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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 15 | NO. 5

MAY

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Low Alloy Steels and Their Applications*

By H. M. PRIEST†

WHEN so much has been written on the general subject of alloy steels, it will be realized that a brief paper, such as this one, can treat the subject only in a cursory manner. In order to limit further its scope, only those steels will be discussed which most naturally find application in the structural and construction fields.

There are many important aspects relating particularly to the metallurgy and production of these steels, but this paper will treat of their physical properties and their applications in industry. Before fabrication can be started there must be careful engineering design. It is well known that alloy steels are somewhat more expensive than ordinary mild steel and consequently it is highly desirable that attention be given to more exact stress analysis and design, with a view to obtaining the full benefit of the superior properties possessed by the alloy steels.

It is these properties which are now bringing engineering thought to the study of the possibilities of alloy steels in various fields. Since the problems of design are intimately associated with the physical characteristics of the material used, it may be of interest to review some of the features of this relationship.

Properties in which the engineer has a vital interest are tensile strength, yield point, elongation, reduction of area, endurance or fatigue limit and resistance to impact. For the benefit of those who may not be familiar with the significance of some of these terms a brief explanation of a few of them will be given.

* Paper presented at March 10th Meeting, New York Section, AMERICAN WELDING SOCIETY.

† Engineer, Railroad Research Bureau, Subsidiary Manufacturing Companies of the United States Steel Corp.

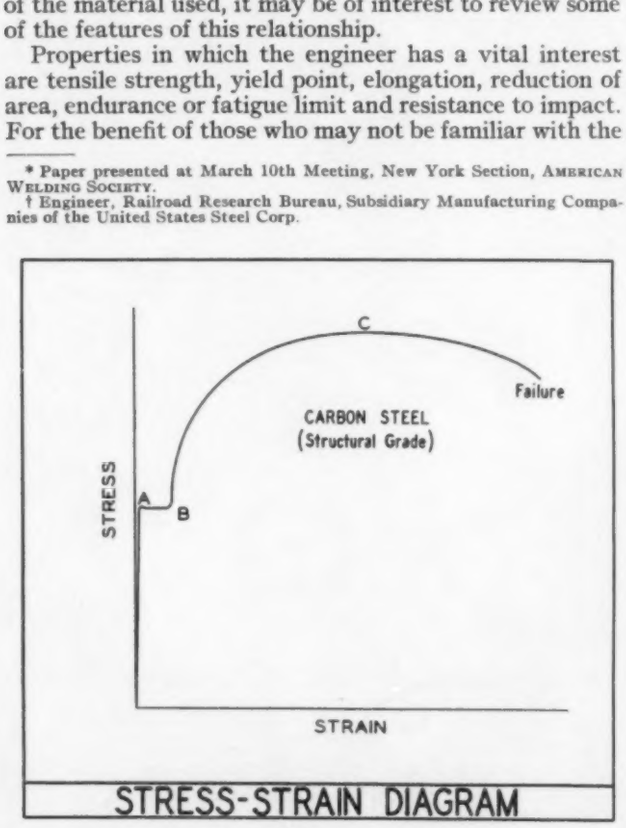


Figure 1

Figure 1 is that of a typical stress-strain diagram for mild steel in which the elongations or strains of a test specimen are plotted against the stresses per square inch. As the stress increases the elongation increases proportionally until we approach the point A, where there is an increasing rate of elongation. The steel exhibits a plastic behavior during this and subsequent stages and the point A is referred to as the yield point of the steel. It will be noted that the elongations increase rapidly at practically constant load and were the load removed at any point beyond A, it would be found that the steel had a permanent set and would not return to its original length and shape. For this reason the yield point holds a very important place in the consideration of design requirements.

The yield point is defined as that stress at which an appreciable extension occurs without further increase in stress. For materials that have a "sharp-kneed" stress-strain diagram this point is satisfactorily determined by the drop of the beam of the testing machine or by means of dividers held against the test specimen until the elongation becomes observable. Where the curve of the stress-strain diagram is smooth and of gradual curvature, without a sharp break, it is general practice to use a percentage of permanent set as the measure of the yield point. The yield strength is defined as the stress at which a material exhibits a specified limited permanent set. This is usually 0.1% or 0.2%.

Returning to the curve in Fig. 1, as the test proceeds, there is a point B at which the steel recovers its ability to resist the stress and the latter then increases to a maximum at point C when failure follows rapidly. The load at C divided by the original cross-sectional area of the specimen, gives the stress per square inch, defined as the tensile strength.

The final percentages of elongation for an original gage length of 8 inches and the 2-inch length within which fracture occurs, together with the percentage in reduction of area, provided information as to the ductility of the steel, which properties predict in part its workability and performance in service.

As just pointed out, the yield point holds special significance for designing engineers. Since elongations increase rapidly with no increase of load, there would be large deformations and permanent sets in any structures when the stresses reached the yield point and the structures would have passed the local limit of their usefulness. Hence it has become quite general practice for engineers to regard the yield point as the limiting property and to base all working unit stresses upon it, using a suitable factor of safety, except for parts under rapidly varying stress or at elevated temperatures.

Coincident with the development of higher tensile steels, is the engineer's search for more accurate means

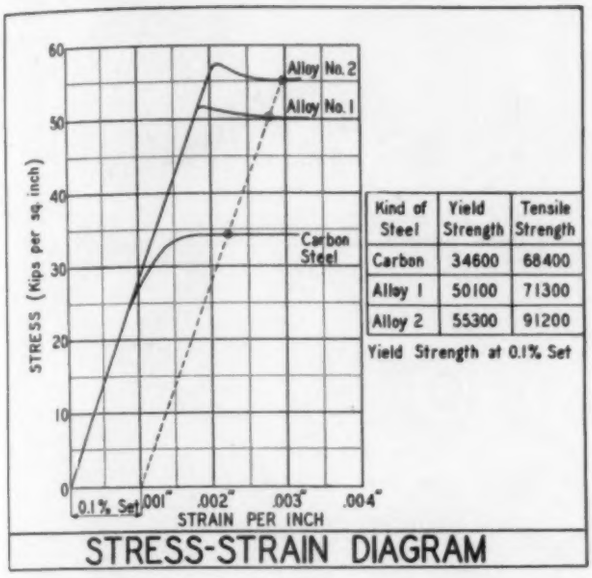


Figure 2

of determining the true stress conditions within the part which he is studying. This is to make possible a more intelligent use of the many desirable properties of these new steels. Then we can apply a consistent factor of safety which will not have to cover so many unknown conditions.

Table 1 gives the physical characteristics of a number of steels which will be identified by their yield points:

Table 1—Physical Properties of Hot Rolled Products up to 3/4 Inch Made on Shape, Plate, Bar and Strip Mills

Property	Mild Steel	Alloy Steel (Yield Point) 45,000	50,000	55,000
Tensile strength	60/72,000	80/95,000	70,000 min.	85,000 min.
Yield point (min.)	33,000	45,000	50,000	55,000
Elong. per cent in 8 inches 3/16 inch and over	1,500,000* / T.S.	1,500,000* / T.S.	1,500,000* / T.S.	1,500,000* / T.S.
Elong. per cent in 2 inches under 3/16 inch		18	22	20

* For material under 5/16 inch to 3/16 inch, inclusive, in thickness or diameter reduce elongation 1.25% for each decrease of 1/32 inch below 5/16 inch.

Figure 2 shows typical stress-strain diagrams for a structural carbon steel and two alloy steels. Since it has just been shown that we are interested primarily in the diagram up to the yield point these curves were carried only to that limit.

Using 0.1% permanent set as indicating the yield strength we have from the curves the following values. The corresponding ultimate tensile strengths are given for reference.

	Yield Strength	Ultimate Tensile Strength
Carbon Steel	34,600	68,400
Alloy Steel No. 1	50,100	71,300
Alloy Steel No. 2	55,300	91,200

It will be observed that the yield points for the alloy steels occur at a higher unit stress than that for the carbon steel. Since the elongations (as shown in Table 1) are satisfactory it is evident that with the same factor of safety, a higher designing unit stress is justified in proportioning the members when made of alloy steels having these properties.

Without going into an extended discussion of design, which could form a separate subject, let us take the simple case of a tension member as illustrative of what may be accomplished with the alloy steels. A factor of safety in common use in a certain field of construction has the value of 1.833 and is applied to the yield point. Using this same factor for our demonstration we obtain the following working unit stresses:

Yield Point	Working Unit Stress
33,000	18,000
45,000	24,500
50,000	27,300
55,000	30,000

Assuming a total stress of 54,000 lb., the tension member would require an area of $\frac{54,000}{18,000} = 3.00$ sq. in. when designed for a steel having a yield point of 33,000 lb. per sq. in. When a steel with a yield point of 55,000 lb. per sq. in. is to be used the required area is $\frac{54,000}{30,000} = 1.80$ sq. in. Here is a saving in area of 1.20 sq. in., or 40% of the area required for the mild steel member. Such increased values of unit stresses are entirely satisfactory if the part is similarly designed as the one referred to in the 33,000 yield point class, or where the character of stress distribution does not introduce unlike conditions.

Corresponding direct percentages of saving are not always obtainable in compression members—particularly when the value of L/r exceeds 60. Engineers are familiar with the fact that beyond this point, the allowable compressive unit stresses converge toward a common value, independent of the yield points of the various steels, because the columns are then approaching a behavior in accord with Euler's formula.

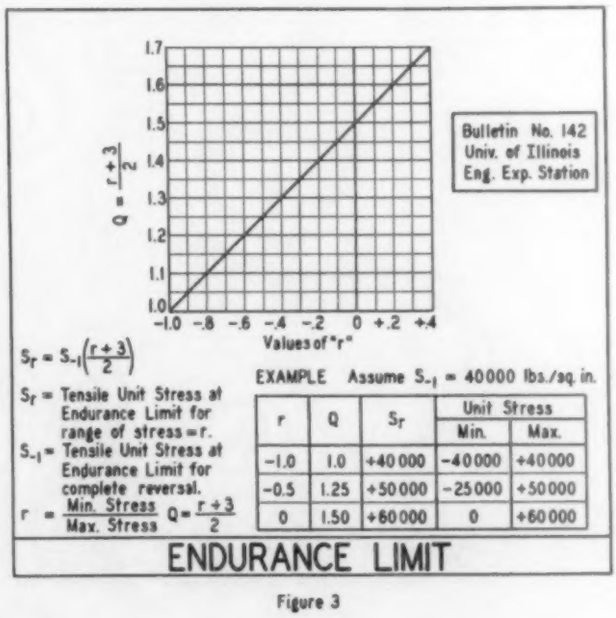

Q = (r+3)/2
Values of "r"
Bulletin No. 142
Univ. of Illinois
Eng. Exp. Station
$S_r = S_{-1}\left(\frac{r+3}{2}\right)$
S_r = Tensile Unit Stress at Endurance Limit for range of stress = r.
S_{-1} = Tensile Unit Stress at Endurance Limit for complete reversal.
$r = \frac{\text{Min. Stress}}{\text{Max. Stress}}$ $Q = \frac{r+3}{2}$
EXAMPLE Assume S_{-1} = 40000 lbs./sq. in.
r | Q | S_r | Unit Stress Min. | Unit Stress Max.
-1.0 | 1.0 | +40000 | -40000 | +40000
-0.5 | 1.25 | +50000 | -25000 | +50000
0 | 1.50 | +60000 | 0 | +60000
ENDURANCE LIMIT

Figure 3

The saving in members subject to bending may depend on another factor, namely, permissible deflection. The modulus of elasticity is practically constant for all grades of steel and with the factors such as span, load and depth of member remaining the same, the deflections will be proportional to the unit stresses in bending. Therefore, the higher working unit stresses permitted for alloy steels will result in greater deflections than those with structural carbon steel members. When these increased deflections would exceed a specified limit it may be impossible to realize the full economy available in the alloy steel. A re-examination of any existing limitations on deflection should be made in such cases and further, the design of a structure may often be altered to reduce the deflection.

There are many structures in which the fatigue or endurance limit values of the steels are of prime importance. In such cases the working unit stresses should be based upon the endurance limit when it is less than the yield strength of the steel. In addition, it is very important to give careful consideration to the design of members subject to fatigue. Such features as abrupt changes of section, insufficient fillets, holes and discontinuities are well-known "stress-raisers" and when not properly taken into account may result in concentrations of stress which will produce the progressive fractures typical of fatigue failure.

The Engineering Experiment Station of the University of Illinois began in 1919 an extensive series of tests on the investigation of the fatigue of metals. In Bulletin No. 142 entitled "An Investigation of the Fatigue of Metals," published by the University, is a formula which gives safe values of endurance limit for wrought ferrous metals under cycles of partially reversed stress or of stress varying from zero to a maximum

$$S_r = S_{-1}\frac{r+3}{2}$$

in which

S_r = Tensile unit stress at the endurance limit for the range of stress represented by r.

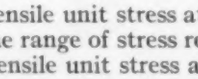
S_{-1} = Tensile unit stress at the endurance limit for completely reversed stress.

r = the ratio of minimum stress to maximum stress for a cycle of stress.

Data are lacking for determining the endurance limit for positive values of r. Figure 3 shows a diagram from

FORMING PRACTISES

Tensile Strength	Hardness Numbers	
	Brinell	Rockwell B
60000	116	68
70000	137	77
80000	159	84
90000	181	90
100000	204	95



Yield Point	W
33000	1.00
45000	1.36
50000	1.52
55000	1.67

	Thickness	Radius of Bend
AM. SHEET & TIN PLATE CO.		
Hot rolled annealed and cold rolled Sheets and Strip	16 gage and thinner	R = T
	Over 16 gage	R = 2T
CARNEGIE-ILLINOIS STEEL CORP.		
Hot rolled Shapes, Plates and Bars	Up to 3/4"	COR-TEN R = 2T MAN-TEN R = 2½T

Figure 4

FORMING PRACTISES

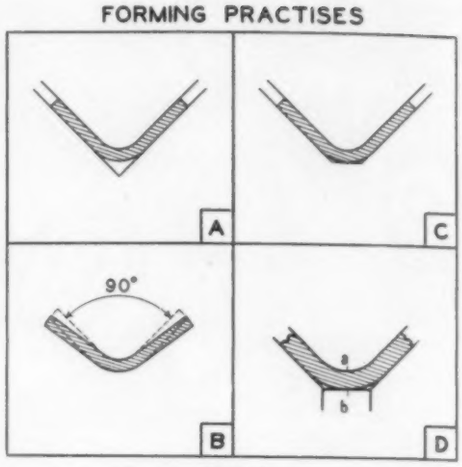


Figure 5

Bulletin No. 142 giving the values of $Q = \frac{r+3}{2}$. An example is given for three values of r, with the resulting values of the endurance limit, starting with a value of S_{-1} = 40,000 lb. per sq. in. for full reversal. When the maximum stress exceeds the yield strength of the steel, the latter should be used as the basis for determining the working unit stress.

Other investigations of fatigue have been conducted and the reader is referred to valuable summaries of work on welded joints given in a Review of the Literature on Bridge Welding published in the AMERICAN WELDING SOCIETY JOURNAL of October 1935.

Any application of high-tensile steel may depend for its success upon the attention which is given to the physical characteristics and behavior of the steel in the fabricating processes. In a brief discussion of this topic, it should be understood that the writer has reference only to the steels made by the subsidiary companies of the United States Steel Corporation.

The high-tensile steels are harder and, in common parlance, stiffer than the ordinary structural grade of carbon steel. In Fig. 4 are listed the Brinell and Rockwell B hardness numbers corresponding to several tensile strengths. While elastically one steel is no stiffer than another, it is frequently said that high-tensile are stiffer. What is meant by such a comparison is that a greater force is required to produce a permanent deformation in such a steel. The additional stiffness may be illustrated by considering the cantilever beam in the upper right-hand corner of Fig. 4. From the previous discussion of stress-strain diagrams it is evident that until the bending stress in the beam produced by the load W is equal to the yield point of the material, there will be no permanent set or deformation. The load W, to produce this stress, will vary directly as the yield point for beams of equal depth.

Taking the load for a steel having its yield point equal to 33,000 lb. per sq. in. as represented by unity, the loads for higher yield points will vary as indicated. In other words, a high-tensile steel will require a greater load to produce permanent set or deformation due to its greater stiffness. It is evident why plates of high-tensile steel in thicknesses equal to those of mild carbon steel require greater pressures in forming operations, but the use of high-tensile steels will result in thinner sections, thus reducing the force required to bring the stress up to the yield strength.

The effective application of the high-tensile steels has brought about an increasing utilization of members

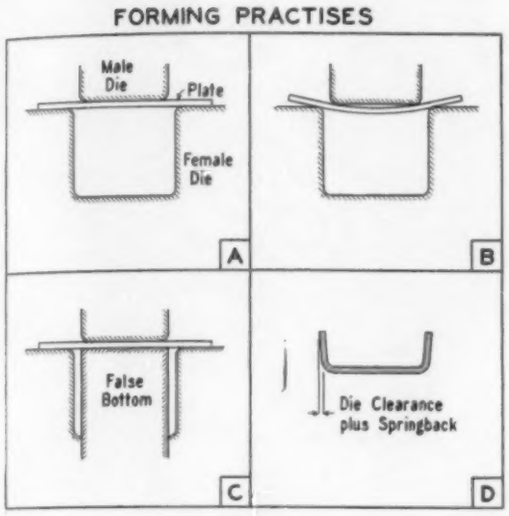


Figure 6

pressed from plates, sheets and strip. The hot pressing of these steels has presented no particular difficulties—a general requirement being that the temperature should be higher, say about 150° F. higher, than is common practice for structural carbon steel.

It is in cold-pressing operations that more care is necessary because of the characteristics of high-tensile steels. There is practical difficulty in attempting to lay down any fixed rules for handling these steels—so much depends upon the available equipment and the skill of the operator, but an experienced fabricator will establish suitable procedures for himself. It may be helpful, however, to make a few observations which will bring out some of the characteristic differences in behavior of ordinary carbon steel and alloy steels.

Experience has shown that generous radii in the corners of pressed parts are desirable. Figure 4 gives the recommended practices for two alloy steels, USS Cor-Ten and USS Man-Ten, produced by the Carnegie-Illinois Steel Corporation and the American Sheet and Tin Plate Company.

Spring-back, in excess of that found with carbon steel, may be encountered with high-tensile steels due to the greater rigidity or stiffness of such steels. Figures 5*A* and 5*C* show two possible forms of dies for pressing a right angle into a sheet or plate. In Fig. 5*A* the female die has a right-angle corner and it will be seen that no pressure is applied to the lower side of the plate between the tangent points. Consequently when the dies are opened and the piece removed, the elastic action of the steel causes the piece to spring back to a greater angle than 90°, as shown in Fig. 5*B*. Since the amount of this elastic action depends somewhat upon the yield point, the high tensile steels with their proportionately higher yield points have the tendency to spring back more than do carbon steels of structural grade.

Figure 5*C* illustrates a method for minimizing the spring-back. The difference from Fig. 5*A* lies in the fact that the dies are so arranged that pressure applied is as shown in Fig. 5*D*. The pressure applied at points "*a*" and "*b*" upsets the material on the surfaces of the plate, so that the elastic action is offset and spring-back is greatly reduced or eliminated.

Still another way to eliminate the effect of spring-back is to press the plate to a smaller angle than 90° and let it spring back to 90°. This is not a very satisfactory way unless there is a sufficient number of pieces to be pressed to warrant special dies, because the allowance will vary with the kind of steel and the thickness of material.

The radius of curvature on the edges of the female dies has an effect upon the spring-back as will be illustrated from Figs. 6 and 7. In Fig. 6*A* is shown a female die with a small radius on the edges. As the dies come together the plate springs away from the bottom of the male die but because of the small radii the plate is quickly gripped between the two dies and no further springing can take place. In some cases, as shown in Fig. 6*C*, a false bottom clamps the plate to the male die and maintains a pressure on the plate as it goes down with the male die. The result of these pressing operations is shown in Fig. 6*D*, in which the piece is shown with the edges of flanges flared out by the amount of the clearance of the dies, plus the spring-back.

Figure 7*A* shows a female die with large edge radii. When the dies come together the plate springs away from the male die as in the previous case, but the large radii permit this action to continue longer before the dies grip the plate. Consequently a larger bulge is formed and is carried down in the female die until it reaches the position shown in Fig. 7*C*. From this point on, the male die squeezes this bulge outward into the lower corners of the female die. Owing to this upsetting action, the flanges of the piece may spring inward as shown in Fig. 7*D*. If the lower corners of the female die are square as shown in Fig. 7*E* there is the possibility of the upsetting being severe enought to crack the piece on the inside surface of the corner of the plate.

It will be evident at once that the elimination of spring-back in pressed sections such as illustrated, depends upon finding the correct radius between the extremes of Figs. 6 and 7 which will balance the two tendencies. This cannot be accurately predicted in advance but is rather the result of trial and correction.

A few instances of difficulties which were encountered in the early applications of high-tensile steels may be interesting. One such dealt with the occasional cracking of some needle beams on an inside angle of channel section, pressed cold from a plate. A sketch of these beams is shown in Fig. 8*A*.

The cause of this trouble lay in the preparation of the

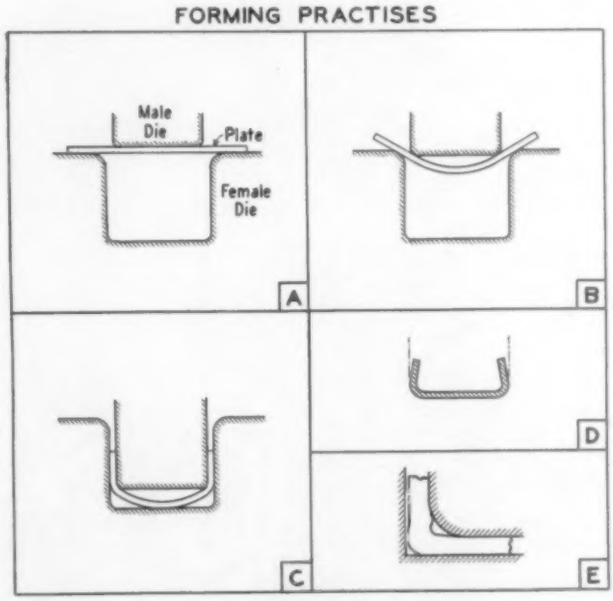


Figure 7

blank. The excess piece of plate (indicated by cross-hatching) had been removed by straight shears, leaving a sharp corner which acted exactly as a notch or nick. It is possible that ordinary carbon steel might have come through without cracking but in this case the plate was of high tensile steel and did not have quite as much ductility—hence, when the notch effect was especially severe, a crack occurred. Had a hole been punched in the corner before shearing, or the blanking knife had a rounded corner, the difficulty would have been avoided. In severe pressing operations it is important to prepare properly any sheared edges subject to bending.

Another difficulty arose in the pressing of the corners of a hopper car door. Figure 8*B* shows such a corner.

In pressing a door from carbon steel it is common practice to cut the corners of the blank with radius knives along a line *ced*, which will produce flanges of about the same height on the corners as on the straight sides. When pressed into shape it is evident that point "*c*" moves to the position "*a*" and likewise point "*d*" moves to "*b*". The edge *ced* has to shorten to a length *agb*. This is accomplished by the upsetting of the steel.

Alloy steels do not have the same upsetting ability and tend to fold over. The corner flanges did not have to be full height and the corner of the blank could be cut along the line *chd*, thus reducing the length of edge to be shortened in the pressing operation. In order to avoid wear on the corners of the female die the distance *hg* should be an appreciable amount, say four times the thickness *T*. When the location of a rivet in the flange is close to the corner it may be necessary to cut the blank along line *cfd* in order to provide the required edge distance in the final pressing.

The suggested radii for the corners are shown in the sketch for cold-pressing operations. In hot pressing, the radius of the corner between flanges can be changed from $3T$ to $2T$ and the radius between the flanges and the flat surface can be changed from $2T$ to once the thickness.

Another method is to remove the metal in the corner with a coping knife which has a rounded fillet as shown in Fig. 8*C*. When the corner has been pressed the edges may be welded together to form an integral joint.

When forming sections in high-tensile steels a somewhat reduced speed of pressing is helpful as it gives the metal greater opportunity to flow. It is also important that the dies should be as smooth as possible. If many pieces are to be pressed the increased cost of harder alloy steel dies is often warranted.

Punching of the high-tensile steels is limited to a somewhat less thickness than for structural carbon steel. Drilling and reaming are best done at lower tool speeds—reduced at least 25% below that for carbon steel. These steels are tougher and harder and require that care should be given to keeping the cutting and punching tools in good condition.

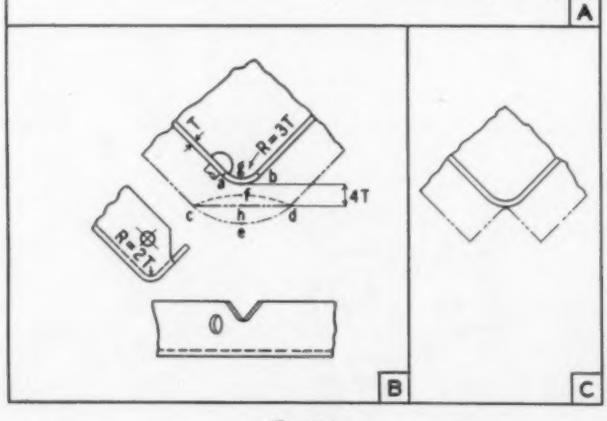


Figure 8

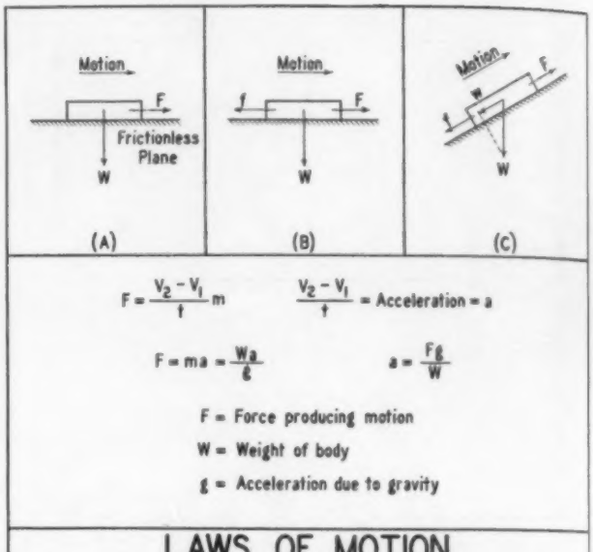


Figure 9

Welding

In general, it may be said that the low alloy steels are readily weldable. The strength of welded joints is an important consideration and can nearly always be made equal to that of the base metal. Many welds can be made with mild steel electrodes and strengthened by adding reinforcements to the butt welds or increasing the size of fillets. There are electrodes which deposit weld metal of high strength. The selection of a suitable electrode can be made from a large number now available, many of which have been designed for a specific steel or group of steels. The welds may approach the chemical analysis of the base metal, because of the alloying elements in the electrode and those which the welds absorb from the material being welded.

The metallurgy of welding is a vital consideration but even with this factor satisfactorily controlled, there are matters of procedure which should be kept in mind. The alloy steels have higher yield points than that of plain carbon steel and for this reason, possess a greater rigidity or inability to adjust themselves to the distortion stresses. The assembly should be so arranged that shrinkage can be met, as far as possible, by free movement of the parts.

Distortion may often be minimized by making the welds in multiple beads so that no large amounts of heat are generated at one time, and with alloy steels the annealing effect of one bead upon the preceding ones may be distinctly beneficial. Another procedure which is often helpful, especially for welding those steels in which the carbon content is relatively high, is to introduce a mild pre-heat of the base metal, which assists in dis-

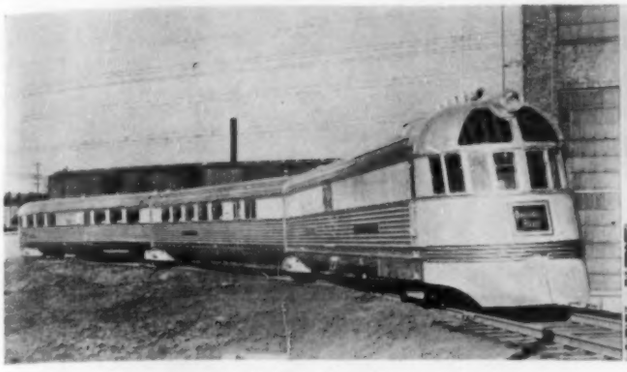


Fig. 10—Burlington "Zephyr"

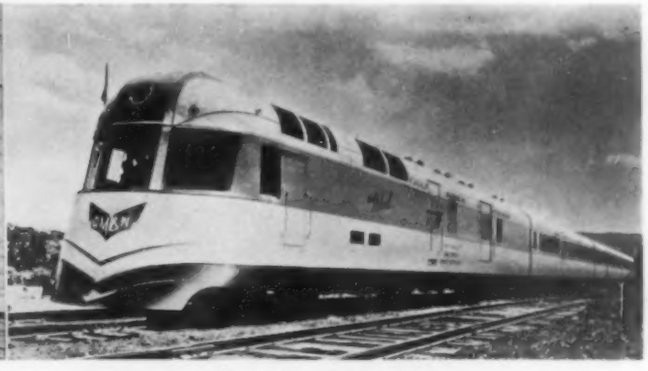


Fig. 11—"The Rebel," Gulf, Mobile & Northern

tributing the distortion and is a valuable factor in reducing the tendency of some steels to harden.

The service to which the welded structure is to be put will determine whether or not it is desirable to stress relieve the structure after welding. Where important fatigue or dynamic stresses are to be encountered in primary members it may be advisable to give the structure a heat treatment. Such a treatment would consist in slowly bringing the welded parts up to a temperature of 1200° F. and holding them at this temperature for one hour per inch of thickness and then allowing the parts to cool slowly, either in the furnace or in still air.

While the reductions in weight, which are possible with high-tensile steels, hold definite advantages in some static structures, the greatest savings are effected in structures which have to be moved. The most obvious advantages in static structures lie in bridges, whereas, in the field of mobile structures, the economies are most apparent in freight and passenger cars, street cars, buses, mine cars and traveling cranes, but many other fields are being investigated to determine what uses are practical and will result in ultimate savings from the standpoint of first cost, operation, maintenance and in some cases, the increased revenue-producing loads made possible by decreasing the dead weight of the car.

During the past two or three years, there has been much in the public press and trade magazines describing numerous examples of the application of alloy steels to railroad rolling stock. From the view-point of popular interest, such examples as the Burlington "Zephyr," "The Flying Yankee" of the Boston & Maine and "The Rebel" built for the Gulf, Mobile & Northern have enjoyed a great appeal and are excellent examples of detailed study of a specific problem in which alloy steels have contributed in large measure to the success of these high-speed trains.

It needs no more profound knowledge of engineering mechanics than can be gained by the driver of an automobile to realize that high speed and quick acceleration can be obtained in one of three ways— increase the power of the engine, decrease the weight of the car and, lastly, reduce the resistance or frictions which operate against the propelling forces. Who has not witnessed the rapid "get-away" of the light-weight car and the ease with which it can pass a heavier car on a hill?

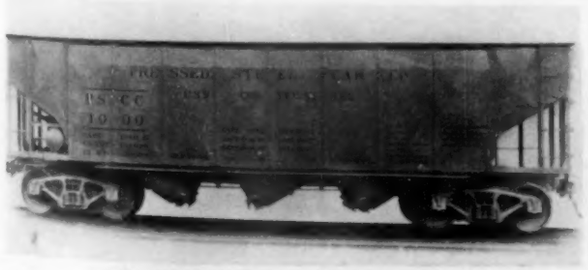


Fig. 12—Car Like Those of B. & L. E. R. R.

For the more exact analysis we can go back to the laws of motion which we have all studied at some time.

$$F = m\,\frac{(V_2 - V_1)}{t} \qquad \frac{V_2 - V_1}{t} = \text{acceleration} = a$$

$$F = ma = \frac{W}{g}\,a \text{ from which } a = \frac{Fg}{W} \qquad g = \text{(gravity)}$$

F = Force acting during the time interval, t
m = Mass of the body
W = Weight of the body
V_1 = Initial velocity ($V_1 = 0$ when body starts from rest)
V_2 = Velocity at end of time interval, t
t = Time interval

From the formula, $a = \frac{Fg}{W}$, we readily see the effect of the two factors, propelling force F and weight W. In order to secure a rapid acceleration, that is, to increase the value of a, we can do it by increasing the propelling force or by reducing the weight.

Figure 9*A* illustrates a body acted upon by the force F and weight W, resting upon a frictionless, level plane. Of course, this is an ideal condition, whereas the actual conditions are represented by Fig. 9*B* in which we have the retarding force f, which includes the friction forces from bearings, air resistance and so forth. The force F must be increased by the amount, f, if we are to have the same acceleration as in the example of Fig. 9*A*.

The further introduction of the condition of motion up a slope, shown in Fig. 9*C*, shows the additional retarding force, w, which is the component of the weight W in a direction parallel to the plane. We now see that the third way of attaining greater acceleration is to reduce the retarding forces. The methods of accomplishing this end are familiar, streamlining being one of the most publicized of all. However, streamlining becomes effective only when speeds greater than about 75 miles per hour have been attained.

Figure 10 is a photograph of the Burlington "Zephyr." It is a three-car articulated train constructed largely of stainless steel, 18–8, and built by the Edward G. Budd Mfg. Co. of Philadelphia. The shotweld process was used to a great extent in joining the members of the car-body structure from floor to roof. The over-all length of the train is about 197 feet and light weight is 195,000 lb. The first car carries the 660-hp. Winton Diesel-electric power plant and baggage and mail compartments designed to carry 50,000 lb. of load. The front end of the second car has an extension of the baggage compartment and the remainder of this car and the entire third car have seats for 72 passengers.

The power plant is carried on an engine-bed of Cromansil steel, fabricated by Lukenweld, Inc., which is of rigid,

Fig. 13—C. & O. Hopper Car

arc-welded construction, annealed after welding was completed.

It is interesting to compare the light weight of 195,000 lb. for this entire train with the weight of about 180,000 lb. for a single standard Pullman car.

This is the train which made the non-stop run of 1015 miles between Denver, Colorado, and Chicago at an average speed of 77.5 miles per hour. The fuel consumption was 418 gallons, the approximate cost of which was $16.00. The maximum speed attained on the run was 112.5 miles per hour.

Figure 11 is a photograph of "The Rebel" of the Gulf, Mobile and Northern, built by the American Car and Foundry Company. The principal material of construction is of a high-tensile, corrosion-resisting alloy steel. Two trains of three cars each were built with a seventh car which is used interchangeably in both trains. Unlike the "Zephyr," just described, these trains are not articulated, but made up of completely separate car units. Except for the center sills, the framework is composed largely of pressed steel members. The sides were built in panel sections of three windows to a section. Each section included the $^{3}/_{32}$-in. sheet, two side posts, a belt-rail stiffener of pressed *Z*-section and a top window stiffener of special *Z*-section. These horizontal members, as well as the posts are spot-welded to the sheets, thus leaving the exterior surface of the sheets smooth and devoid of rivet heads. A small angle spot-welded to the vertical sides of the panels on the inside permits the panels to be joined and riveted together. The outside joints between the sheets were then arc-welded. The carlines are pressed channels to which the roof sheets were spot-welded. The sheets are welded to the side sheets to give an unbroken surface over the roof of the car.

Less spectacular, but fully as important, are the applications of alloy steels to the several types of freight car equipment. Let us begin with the hopper car. Such cars are designated by their nominal load carrying capacity, such as a 50-ton or 70-ton car, to refer to the most common types. It may be interesting to some readers to know how this rating is determined. A 50-ton car has $5^{1}/_{2}$ x 10 journals, meaning $5^{1}/_{2}$ inches diameter by 10 inches long, upon which the Association of American Railroads permits an axle load of 40,000 lb. or 20,000 lb. per journal. With four axles per car this makes a total axle load of 160,000 lb. To this load is added the weight of the wheels and axles, 9000 lb. in this case, making a total rail load of 169,000 lb. which is the starting point in the design of any 50-ton car. Similarly, for a 70-ton car, the start is made from a rail load of 210,000 lb.

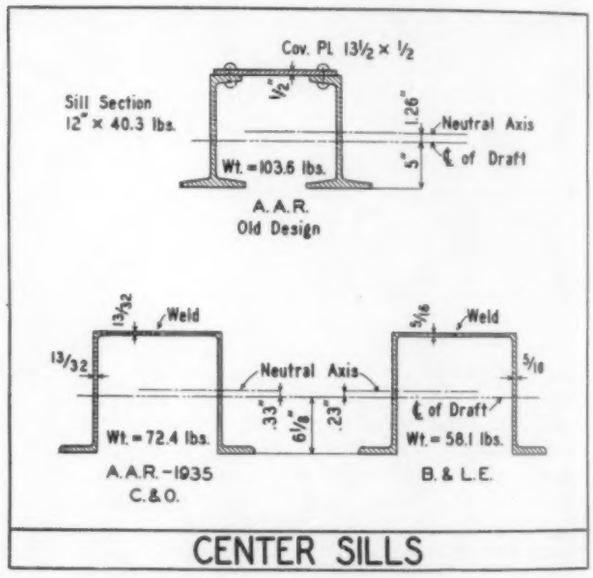
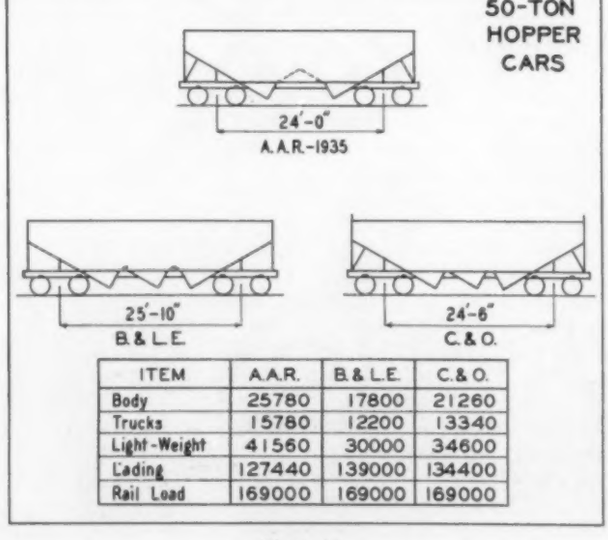


Figure 15

SUMMARY OF WEIGHTS



ITEM	A.A.R.	B.& L.E.	C.& O.
Body	25780	17800	21260
Trucks	15780	12200	13340
Light-Weight	41560	30000	34600
Lading	127440	139000	134400
Rail Load	169000	169000	169000

Figure 14

Few people, not directly concerned with railroad equipment, realize how important are the interchange requirements—those rules, regulations and standards which permit of repairs to a car wherever it may be and make possible its handling in any trains on any railroad of standard gage. These requirements often limit the changes which can be made in re-designing railroad rolling stock.

Hopper Cars

Figures 12 and 13 are photographs of two recent examples of light-weight designs in which alloy steels have been extensively used. The first is that of one like a hundred cars built for the Bessemer and Lake Erie Railroad by the Pressed Steel Car Company. The other was built for the Chesapeake and Ohio Railway Com-

pany by the American Car and Foundry Company. It will be informative to examine a summary of weights and to see what savings were accomplished and the principal items which contributed to the final results.

Figure 14 shows a weight summary for these two cars and for comparison purposes the 1935 design of the Association of American Railroads is given. It will be observed that the B. & L. E. car shows a reduction of light weight of 11,560 lb. and the C. & O. car of 6960 lb. from that of the A. A. R.-1935 car. The allowable weight of loading increased correspondingly, giving higher ratios of pay load to dead load.

The following tabulation lists a few of the principal items which contributed to the weight reduction.

Another light-weight design is that built by the Pullman-Standard Car Mfg. Company from its own plans. Figure 17 is a photograph of the finished car. The total weight of this car is 10,200 lb. less than that of the standard A. A. R. design. A large amount of welding was employed in its fabrication which involves 22% of arc welding, 54% spot welding and 24% riveting, based upon length of seams. The sides, ends and roof were fabricated into individual units by means of special jigs and welding the sheets to the structural framework. When assembled in the car body the parts were riveted together on the corners.

The car body is of high-tensile steel. The light *Z*-section center still was used as in the Mt. Vernon car. An interesting construction is the substitution of welded assemblies for the usual cast steel bolster center filler, front and rear draft lugs and striker. Each bolster consists of $^{5}/_{32}$ pressed pans with top and bottom cover plates 21 x $^{5}/_{16}$. The four crossbearers consist of two $^{1}/_{8}$-in. pans with top and bottom cover plates while the two floor beams are of two $^{1}/_{8}$-in. pans extending from center to side sill.

The side sheets are 0.05-in. sheets, each pressed with two $^{1}/_{2}$-in. deep corrugations extending vertically, are spot-welded to the side plate, posts and sill. The top end sheets are $^{3}/_{32}$ in. thick and the lower sheets are $^{1}/_{8}$ in. thick. The eleven carlines are $^{3}/_{32}$-in. pressed channel sections to which the 0.05-in. roof sheets are

Part of Car	A.A.R.-1935	B. & L. E.	C. & O.
Side Sheets	$^{3}/_{16}$ in.	$^{3}/_{32}$ in. buckled	$^{1}/_{8}$ in.
Top Floor Sheets	$^{1}/_{4}$ in.	$^{3}/_{32}$ in. buckled	$^{3}/_{16}$ in.
Bottom Floor Sheets	$^{1}/_{4}$ in.	$^{1}/_{8}$ in.	$^{5}/_{16}$ in.
Hopper Sheets	$^{1}/_{4}$ in.	$^{5}/_{32}$ in.	$^{3}/_{16}$ in.
Top Angles	Bulb *L* 5 in. x 3$^{1}/_{2}$ in. x 13.2 lb.	Bulb *L* 5 in. x 2$^{1}/_{2}$ in. x 7.3 lb.	Bulb *L* 5 in. x 2$^{1}/_{2}$ in. x 8.5 lb.
Side Sills	*L* 5 in. x 3$^{1}/_{2}$ in. x $^{3}/_{8}$ in.	*L* 4 in. x 3 in. x $^{5}/_{16}$ in.	*L* 5 in. x 3$^{1}/_{2}$ in. x $^{1}/_{4}$ in.
Spacing of Stakes (av.)	3 ft. 0 in.	3 ft. 2$^{3}/_{4}$ in.	3 ft. $^{3}/_{4}$ in.

The new A. A. R. *Z*-type center sill makes possible another saving in weight as is brought out in Fig. 15. The old style of center sill construction in a previous design of 50-ton hopper car weighed 103.6 lb. per ft. The *Z*-section sill in carbon steel which was used in the A. A. R.-1935 car and the C. & O. car weighed only 72.4 lb. per ft. This sill is composed of two *Z*-sections welded together along the edges of the top flanges. The B. & L. E. car sill was rolled to a reduced *Z*-section in high-tensile steel and weighed 58.1 lb. per ft.

A portion of this weight saving is made possible through the reduced eccentricity of the center line of draft which lessens the stresses produced by the bending on the section from the end loads.

A few joints in the new cars around the hoppers and longitudinal hoods were sealed with welding. Further developments are possible in which welding will play an important rôle and will effect additional savings in weight.

Box Cars

Turning now to another type of car let us look at what has been done with the house or box car. There are several styles but for our consideration let us take as the basis for comparison the standard design of the A. A. R. 50-ton box car.

Figure 16 is a photograph of a car designed and built by the Mt. Vernon Car Mfg. Company along the conventional lines of the A. A. R.-1932 design. High-tensile steel effected a weight saving in the body of the car of 5410 lb. or 26.8% of the corresponding weight of the standard A. A. R. box car fabricated with ordinary carbon steel. The same reduced *Z*-section center sill as used on the B. & L. E. hopper cars was placed in this car. Structural shapes were scaled down in thickness and sizes to about the equivalent strength of members in the original car. In some cases it was necessary to utilize pressed shapes to obtain the proper reduction. Dreadnaught ends and Murphy solid steel roof were of reduced thickness in high-tensile steel. The side sheets on the A. A. R. car were 0.10 in. in thickness while the Mt. Vernon car used a thickness of 0.06 in.

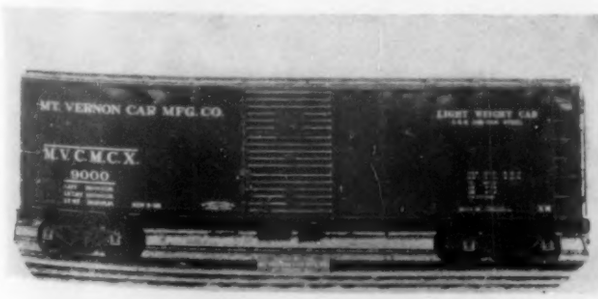


Fig. 16—Mt. Vernon Box Car

Fig. 17—Pullman-Standard Box Car

Fig. 18—New Haven Coach

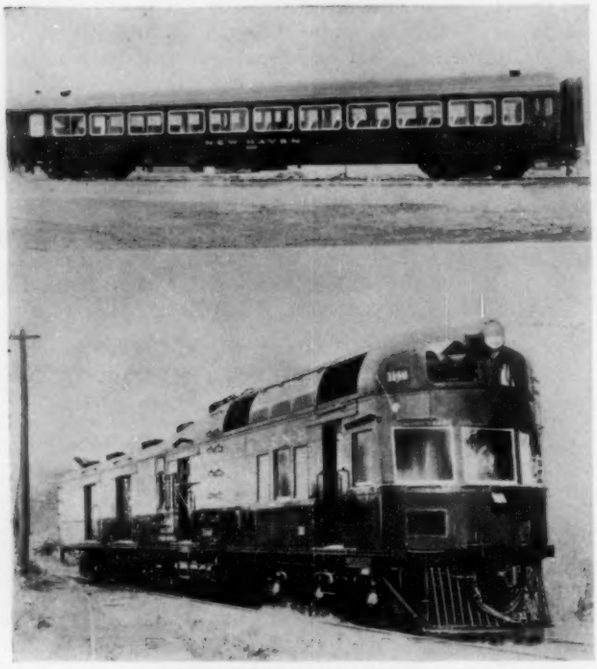


Fig. 19—Boston & Maine Rail Car

spot-welded. Each roof sheet is corrugated in the same manner as the sides.

The following table summarizes briefly the weights of the Mt. Vernon and Pullman-Standard light-weight cars and also lists the standard A. A. R.-1932 design.

	Mt. Vernon	Pullman-Standard	A.A.R.-1932
Body-	22,740	20,240	27,800
Trucks	13,660	13,960	15,600
Light Weight of Car	36,400	34,200	43,400
Load Limit	132,600	134,800	125,600
Rail Load	169,000	169,000	169,000

New Haven Streamline Coaches

Fifty coaches, like the one shown in the photograph of Fig. 18, were built for the New York, New Haven & Hartford by the Pullman-Bradley Car Corporation. The coaches are 84 ft. $6\frac{1}{4}$ in. long over the buffers and weigh approximately 100,000 lb., which is a saving of about 36,000 lb. This weight reduction was effected by the use of alloy steels in the body of the car. The underframe is largely constructed of pressed steel shapes and likewise the superstructure framework utilizes pressed shapes and is covered with sheets—all of low-alloy high-tensile steels.

It is interesting to note the streamlining which avoids all projections and makes the exterior surface as smooth as possible. Windows and doors are nearly flush and the roof is of turtle back construction, while a smooth skirt projects below the car floor to the level of the steps. All these items improve air flow and give the car a trimmer appearance.

Boston & Maine Rail Car

This rail car of the Boston & Maine, shown in Fig. 19, was built by the St. Louis Car Company. It is powered with a 12-cylinder Diesel-electric unit of the Westinghouse Electric and Manufacturing Company and is capable of handling trains made up of standard coaches and Pullman.

The underframe of this car was fabricated from high-tensile steel and is of welded construction throughout. The center sill consists of two 9 in. x 25.4 lb. ship channels with 18-in. cover plates, top and bottom, forming a box girder. Front and rear bolsters were cut to shape from plates and welded into box sections. The needle beams are of similar construction, but in the form of *I*-sections. Crossbearers are of channel sections, pressed from $\frac{5}{16}$-in. plate, having 5-in. webs and 2-in. flanges. They are welded to the center and side sills on the edges of contact.

The engine room floor plate was welded to the underframe members to form an oil-tight, unit frame from bumper to the rear end of the engine room. A structural frame, welded to the floor, anchors the power plant.

When loaded with 14,000 lb. of supplies and 25,000 lb. of mail and baggage the car weighs 250,000 lb. The motors are geared to develop a maximum speed of 86 miles per hour.

Street Cars

About six years ago the Electric Railway Presidents' Conference Committee was organized to make research studies and to produce improved designs for street cars. One of the cars developed by the Engineering Staff of the Conference Committee and built by the Pullman Car and Manufacturing Corporation is shown in Fig. 20. High-tensile steel was used in the construction of the body. Welding was extensively used in joining the members of the frame and in attaching the covering sheets to the frame. The weight of the complete car is approximately 31,000 lb. Older types of cars average about 50,000 lb. in weight.

The Capital Transit Company of Washington, D. C., purchased twenty surface cars of modern design—ten built by the St. Louis Car Company and ten by J. G. Brill Company. Figure 21 is a photograph of one of the cars of the J. G. Brill Company. The body framing and covering sheets of all twenty cars are of high-tensile steel, welded together to form an integral structure.

Fig. 21—Capital Transit Car

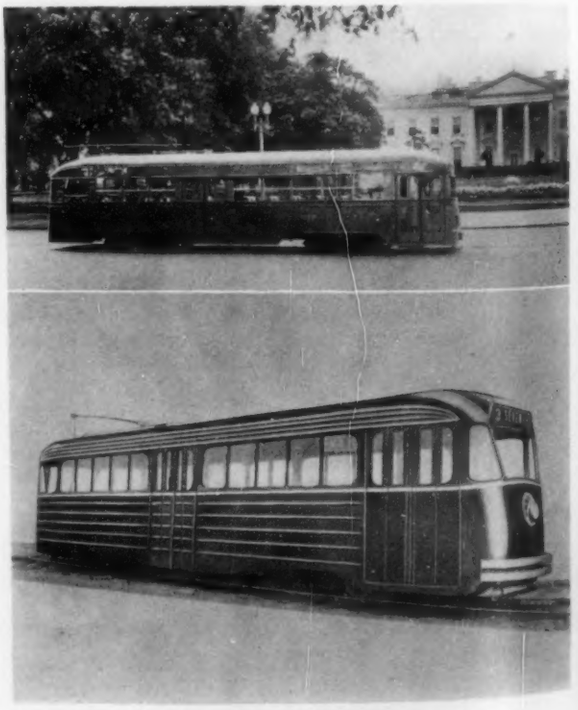


Fig. 20—Presidents' Conference Committee Car

Fig. 22—Delaware River Joint Commission Car

Delaware River Joint Commission Car

Figure 22 is a photograph of one of the cars for the Delaware River Joint Commission. It was designed by the Commission and twenty-six such cars are being built by the J. G. Brill Company. The underframe, superstructure and the roof and side sheets are of high-tensile steel. The center sills are of 8-in. channels and 5 x 3 x $^{5}/_{16}$ angles were used for the side sills. Pressed sections were utilized for the body bolster diaphragms, needle beams, posts and carlines.

Quarry Cars

The service conditions in the quarries of the Pittsburgh Limestone Company are severe for the cars that carry the limestone from the workings to the crushers. One of the cars recently built for this service is shown in Fig. 23 and a glance at the sizes of the rock, which is loaded by steam shovel, will readily convey an idea of the operating demands upon the car structure.

This car was built by the Lorain Division of the Carnegie-Illinois Steel Corporation. A high-tensile steel was used for the body and electric arc welding was employed in its fabrication. The floor of the car is supported on U-section members which are intermittently welded to the floor. The vertical ends are welded to the floor plates and are stiffened by U-section members. The car weighs 12,000 lb. and has a load capacity of 11 net tons. Weight reduction was not of primary consideration, but rather the utilization of the greater resistance of a high-tensile alloy steel to the denting from the rock masses.

Fig. 23—Quarry Car

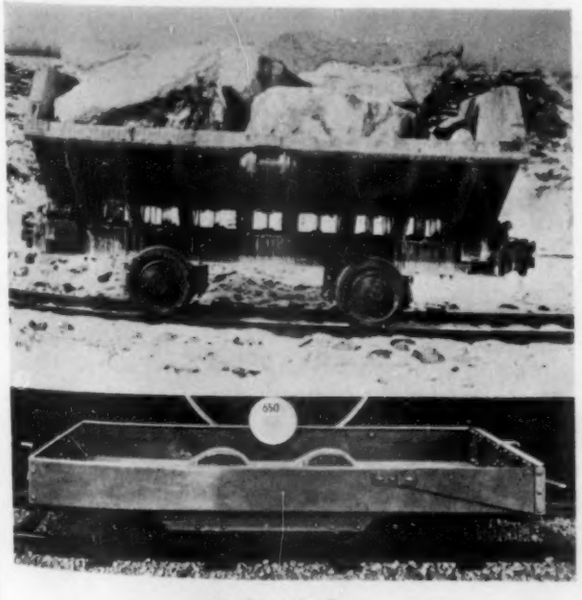


Fig. 24—Mine Car

Mine Cars

The advantage of light weight in mine cars is easy to appreciate. Limited in size and capacity because of the cramped conditions under which they have to be operated, these cars have possibilities for weight reduction. In the one shown in Fig. 24, an alloy steel possessing corrosion resistance distinctly superior to that of carbon steel was used in the sheets and portions of the frame in contact with the lading. Weight savings of 25 to 30 per cent may often be effected by employing such an alloy steel.

Locomotive Side Frames

A process, closely allied to welding, is that of flame cutting by means of the oxyacetylene torch. An interesting development, employing this cutting process, is the production of locomotive frames from rolled steel slabs. Figure 25 shows one of eight frames for four locomotives of the 2-8-4 type recently built for the Detroit, Toledo & Ironton by the Lima Locomotive Works, Inc. The material is a normalized and tempered carbon steel possessing a high degree of homogeneity.

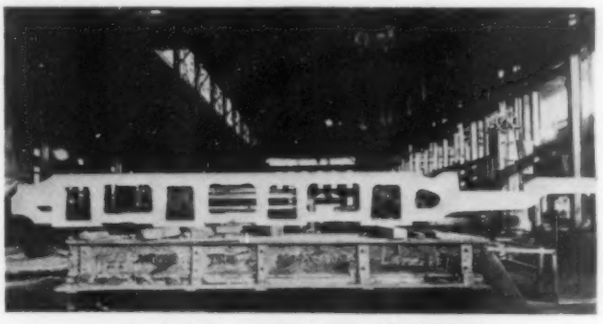


Fig. 25—Locomotive Side Frame of Rolled Steel

Test-pieces were taken from several points in the metal removed from each pedestal and showed the following ranges of results:

Yield Point	40,540 to 45,180 lb. per sq. in.
Tensile Strength	71,800 to 79,940 lb. per sq. in.
Elong. in 2 In.	29.5% to 32.0%
Red. in Area	53.3% to 56.0%

The frames were furnished by the mills as shown in the photograph and the final machining was done by the Lima Locomotive Works. The slab from which the frame was cut was $35^{5}/_{8}$ x $6^{1}/_{2}$ x 36 ft. $5^{1}/_{2}$ in. and weighed 24,765 lb. While carbon steel was used for these locomotive frames, future developments will undoubtedly find alloy steels playing their part—in fact, an inquiry has already appeared for frames in which a low nickel, chrome steel was specified.

Coal Dock

Figure 26 is a photograph of Dock No. 24 in Cleveland, owned by the Pennsylvania Railroad and used in loading coal into lake boats. An alloy steel, known as "abrasion-resisting steel" has been employed in the pan and side walls as well as in the chute neck. In a similar dock of the New York Central at Ashtabula, Ohio, also lined with abrasion-resisting steel, 8,500,000 tons of coal

Fig. 26—Coal Loading Dock

passed over $^1/_4$-in. plate in the neck of the pan with less than $^1/_{16}$ in. of wear.

San Francisco-Oakland Bay Bridge

Many of the notable long-span bridges have contained large tonnages of alloy steels. Figure 27 is a progress photograph of the San Francisco-Oakland Bay Bridge now being erected by the American Bridge Company. The bottom chords for four panels either side of the cantilever pier are made of nickel steel having a yield point of 55,000 lb. per sq. in. The remainder of the bottom chords is of structural silicon steel and this same steel is used in the end top chord and the main vertical members.

One especially interesting use of an alloy steel (silicon steel) is in the derricks which are to be seen on the ends of the cantilever. Each derrick has a mast 118 ft. high and a boom 100 ft. long. The use of silicon steel reduced the weight of the derrick by about 25% as compared to a similar derrick of carbon steel. The lifting capacity was further increased by about 25%. In large derricks with long masts and booms the bending stresses due to dead weight and unavoidable eccentricities become a very considerable item and the alloy steel accomplishes a reduction of weight while permitting the use of higher working unit stresses.

Fig. 27—San Francisco-Oakland Bay Bridge

Conclusion

The several examples of actual applications of low-alloy, high-tensile steels have been selected to show the varied fields in which these steels are being utilized. The controlling reasons for their utilization may vary with the different applications—in many cases, the reduction of weight, in others the increased corrosion resistance possessed by certain steels combined with high-tensile properties and again the value of increased strength over mild steel without increase of weight. In all cases, it is the special characteristics of the high-tensile steels which lend themselves to the development of successful applications in diversified fields of industry.

An understanding of the inherent properties of the low-alloy, high-tensile steels and the behavior of these steels in fabrication is essential to their effective use in any application. This paper has aimed to present some observations which may prove helpful to those who are concerned with such problems. High-tensile steels will be found worthy of careful study.

Welded Frame in Hydraulic Press

By GEORGE M. GILLEN†

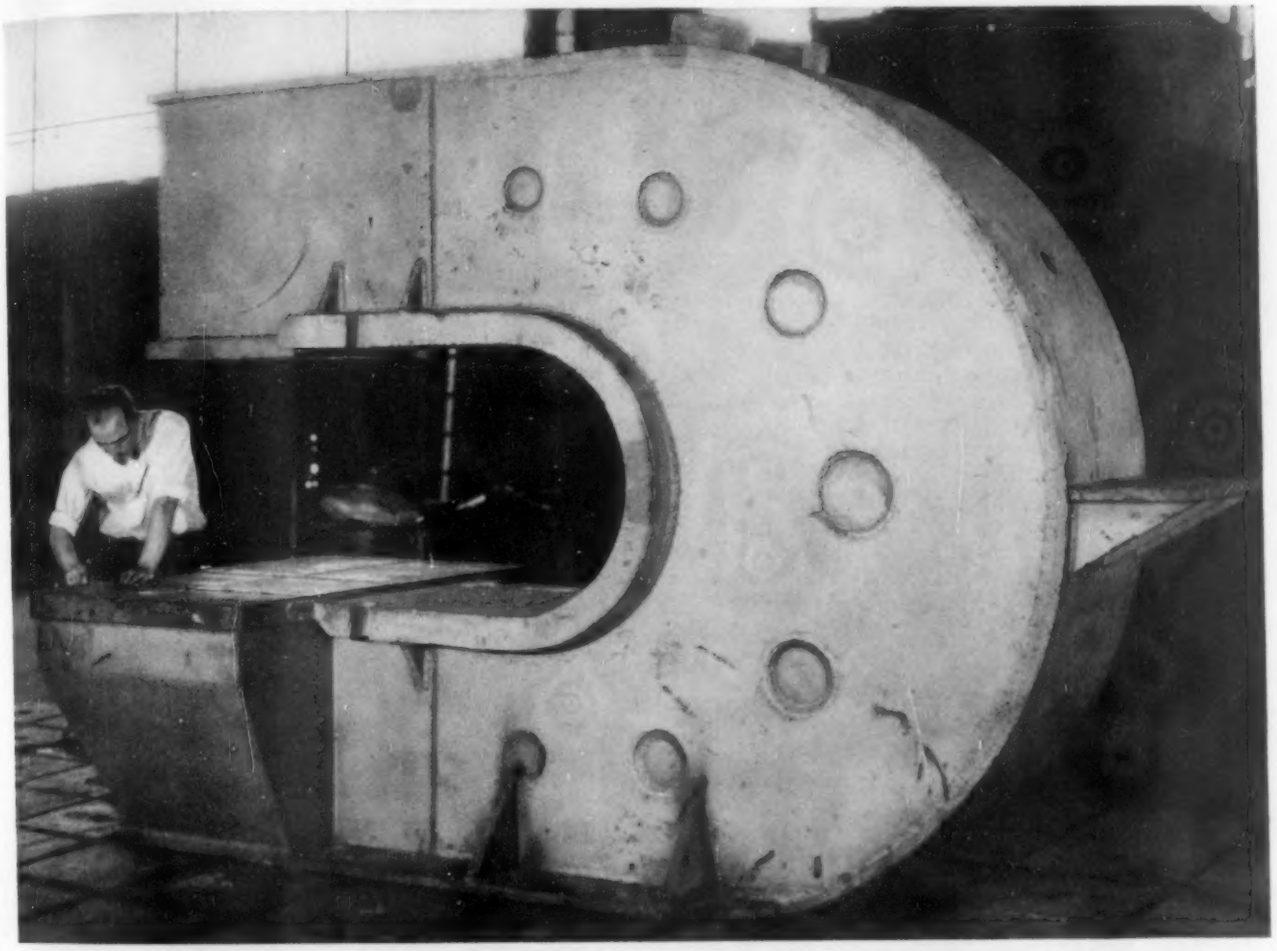
THE Denison Engineering Company, Manufacturing Engineers of Delaware and Columbus, Ohio, recently designed and built a 100-ton hydraulic press which is installed in an eastern plant where it is used for straightening shear blades, steel plates and ploughshares, as well as for certain hot-forming operations.

The maximum piston movement of the press is 17 inches, with a speed of 8 inches in two seconds at low pressure, and at variable speeds up to 1 inch in two seconds at high pressure. The throat is 5 feet in depth from the center of the ram to the rear of the throat, while the throat opening is 28 inches high, and the daylight opening 16 inches. Both the press plunger and the lower platen are cross-key-wayed and provided with threaded holes for affixing and aligning straightening or forming dies. The press is capable of exerting a maximum pressure of two hundred thousand pounds.

The press is equipped with a welded steel frame, designed and built by our Company from a special analysis of welding quality steel. Welding was done with covered electrodes and under insurance welding control. Before shipment, the welded structure was thoroughly furnace-annealed to eliminate any stresses which may have been introduced in the welding process.

The top platen measures 24 inches in width, $25^1/_2$ inches in length and was flame-cut from a $2^1/_2$-inch steel plate. The bottom platen, measuring 60 inches by 36 inches, was flame-cut from a steel plate three inches in thickness. The throat member was formed from a steel

† Sales Promotion, Lukens Steel Company.



Welded Steel Frame Weighing 15,400 Lb., Designed and Built by Lukenweld, Inc., Coatesville, Pa., for 100-Ton Hydraulic Straightening Press Designed and Built by The Denison Engineering Company, Delaware, Ohio. (See also illustration on front cover)

plate 4 inches thick. The main webs and the rear flange are steel plates $1^1/_4$ inches in thickness. The interior stiffening members are $^5/_8$-inch steel plates, spaced on 45 degree angles from the center of the throat radius. The lower platen is substantially braced in all directions in an effort to minimize local deflections.

In the upper portion of the frame is a built-in oil reservoir containing the hydraulic oil supply. The hydraulic cylinder is fitted into the interior portion of the frame at the extreme upper front. The motor-driven hydraulic pump, together with the relief valves, by-passes and other auxiliaries, is mounted directly on top of the frame. The construction provides a self-contained unit, operation being effected by merely connecting to a power supply. This feature, in conjunction with the comparatively light weight of the complete press, provides a high degree of mobility in the unit.

The welded steel frame weighed only 15,400 pounds as shipped from the weldery. The complete press weighs 23,000 pounds. Since it is estimated that the same press with a cast frame would have a minimum weight of approximately 35,000 pounds, the saving in weight effected through the use of welded steel construction may be estimated at 12,000 pounds.

Fall Meeting American Welding Society

in conjunction with Metal Congress Exposition
Cleveland—Oct. 19-23, 1936

Program of Unusual Interest—Plan to Attend!

Maintenance of Way Welding*

By C. A. DALEY†

RAILROAD Maintenance of Way officers and employees are charged with a great deal of responsibility. From the Chief Maintenance officer down to the humble trackman rests the responsibility of millions of dollars of peoples' savings and thousands of lives. Each officer and employee has his share in this responsibility.

Railway Maintenance is the maintaining of the physical properties of the railroad, such as track, buildings, bridges and other facilities. The maintenance of track which consists of rail, ties, fastenings and ballast, is probably the largest item and the most important, because over it passes the heavily loaded freight trains and swiftly moving passenger trains.

During the last decade railroads have suffered a considerable loss of traffic, due to improved inland waterways and highways. This loss of tonnage, together with the falling off of tonnage due to the depression and the drouth, has resulted in decreased earnings and naturally a decrease in the amount of money available for maintenance.

In the face of decreasing amounts authorized for track maintenance, Maintenance Engineers have been called upon to maintain track for increased speeds and heavier power and rolling stock. The mere laying off of forces and curtailment of repairs to certain classes of facilities did not solve the problem. More constructive measures were necessary.

There are four general directions in which action has been taken to accomplish the desired results. First, the conservation of materials and their reclamation; second, improved methods of organization and supervision to obtain greater output for the expenditures allowed; third, the budgeting of expenditures so that work could be done in the proper sequence; fourth, the adoption of labor-saving tools and devices.

One of the largest items of expense in track maintenance in normal years is rail. There are some 280,000 miles of first main track in the United States. It can therefore readily be seen that in normal years the annual rail renewal bill is tremendous.

In order to have good riding track it is as necessary to maintain good rail conditions as it is good line and surface. It is out of the question to have good riding track when the ends of the rails are badly battered.

Rail and batter has been a serious problem for many years and until recent years there was not much that could be done about it without removing the rails from the track. It is here where the Maintenance Engineers have found an opportunity of large proportions for conservation and reclamation of material.

When rail batter reaches $^3/_{64}$ inch the condition is readily felt in riding over the track. The maintenance of such track requires excessive expenditures and constant supervision, or the track will soon become unfit for high speed service in spite of the heavy maintenance costs. In the past such rail was replaced with new rail and the salvaged rail used on branch lines or in yards and sidings. This involved an expenditure for labor of approximately $1200 per mile but further use of the rail was obtained. However, by this method, considerable good rail, except for the battered ends, was lost to main line traffic. Later, rails with battered ends were shipped to a rail sawing plant, where 12 to 18 inches was sawed off each end. The rails were re-drilled and after being classified for height and side wear were again laid in main track. This extended the service life of the rail in main track about 50 per cent at a cost of approximately $1600 per mile.

The more recent method of correcting rail end batter and extending the service life of the rail is welding. By this method the rail ends are reconditioned in the track at the small expense of $300 or less per mile, and the full length of the rail is preserved.

There are two processes by which rail ends are reconditioned in track—the electric arc and the oxyacetylene.

In the electric arc process the worn and battered rail ends are brought up to surface wholly by the addition of metal, sufficient metal being applied to allow for grinding. In this process of reconditioning rail ends, single and two arc machines are used. Since there is considerable excess metal to be removed on an arc-welded joint, one grinder is generally used for each arc. A single arc machine will weld from 45 to 65 joints per day, depending on the length of weld and traffic conditions. When the rail ends are close together the weld is made across the joint. When this is done the joint should be crosscut promptly to prevent an irregular break when the rails contract.

The electric process is recommended for building up castings of high manganese content, such as manganese crossings and frogs and other castings, such as dipper teeth.

The oxyacetylene process affords two distinct methods of reconditioning rail ends, both employing the high temperature of the oxyacetylene flame, but one without fusion, known as "reforming" and the other with fusion, known as surface fusion welding. Both methods employ substantially the same apparatus and equipment.

* Presented before the Pacific Railway Club at joint meeting with San Francisco Section, A. W. S., Jan. 9, 1936.

† Maintenance of Way Engineer, Air Reduction Sales Company.

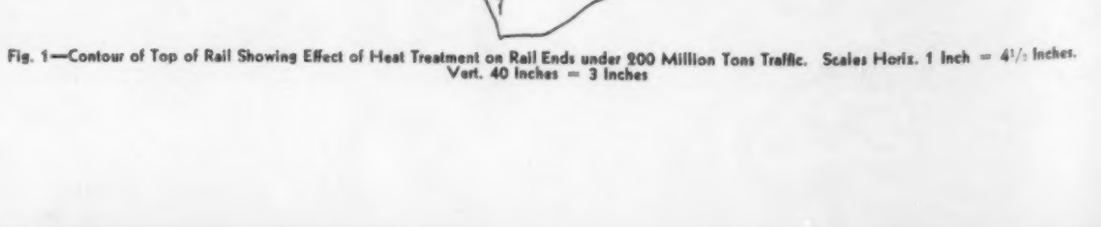


Fig. 1—Contour of Top of Rail Showing Effect of Heat Treatment on Rail Ends under 200 Million Tons Traffic. Scales Horiz. 1 Inch = 4½ Inches. Vert. 40 Inches = 3 Inches

Fig. 2—Building up Battered Rail Ends

They can be used separately and independently of each other, or if conditions warrant, the two methods can be used jointly in reconditioning rails.

Where Recommended

The reforming process is recommended for reconditioning rail ends where only a slight amount of batter exists. As a rule, rail ends with $^3/_{64}$ inch or less batter can be reconditioned without the addition of any welding rod unless, of course, the rail end is chipped, in which case metal is added.

The surface fusion weld process, as distinguished from the puddling process, is followed when the batter exceeds $^3/_{64}$ inch and does not exceed $^1/_8$ inch, or where a long batter exists.

Description of Reforming

The reforming process for reconditioning rail ends not only produces a very satisfactory joint, but permits of a larger output of joints per man. This results in a lower unit cost per joint than the ordinary methods of welding, especially when only a small amount of batter exists. The procedure in this operation is as follows:

1. A straight-edge is laid across the joint to determine the exact extent of the batter. The limits of batter are then marked on the rail, or a mental record made by the operator, who then heats the center of the rail to a forging heat within the limits of the batter. The helper with a sledge then drives up the center of rail by striking along each side of the ball of the rail within the limits of the heated area.
2. Heat is then applied to the rail head more or less in the shape of a letter "U," with the open end of the "U" toward the end of the rail, thus heating the rail head on either side of the center. The sledge is again brought into play as before. This will raise the surface of the rail from the center out toward the sides. The completion of this operation will bring the rail up to the desired surface except at the end of the rail where the batter is always the greatest.
3. The next operation is to heat across the rail an inch or so from the end. A hot-cut chisel of the proper thickness and about $2^1/_2$ inches wide is driven between the rail ends. This will raise the surface of the rail at the ends and produce the desired height of the ends.
4. A straight-edge is then placed on the rail in order to locate any low spots. If any are found, metal is added.
5. If the flatter method is used for finishing, the whole end of the rail within the reforming area is then heated and a finished surface made by the use of the flatter and sledge.
6. The other rail end forming the joint is then worked in the same manner. Upon completion of the reforming of this rail end the two rail ends are heated and brought to the same height by working the flatters across the joint.

On a completed joint the straight-edge should swing freely from the junction of the two rail ends while the rail is hot. Upon cooling the joint will be in line.

In this method of reconditioning rail ends, as in any other by oxyacetylene process, any loose metal is readily detected when the heat is applied. If any shows up it should be melted out and new metal added.

Surface Fusion Welding Technique

This method of reconditioning rail ends differs from

Fig. 3—Applying Heat in Drawing Operation

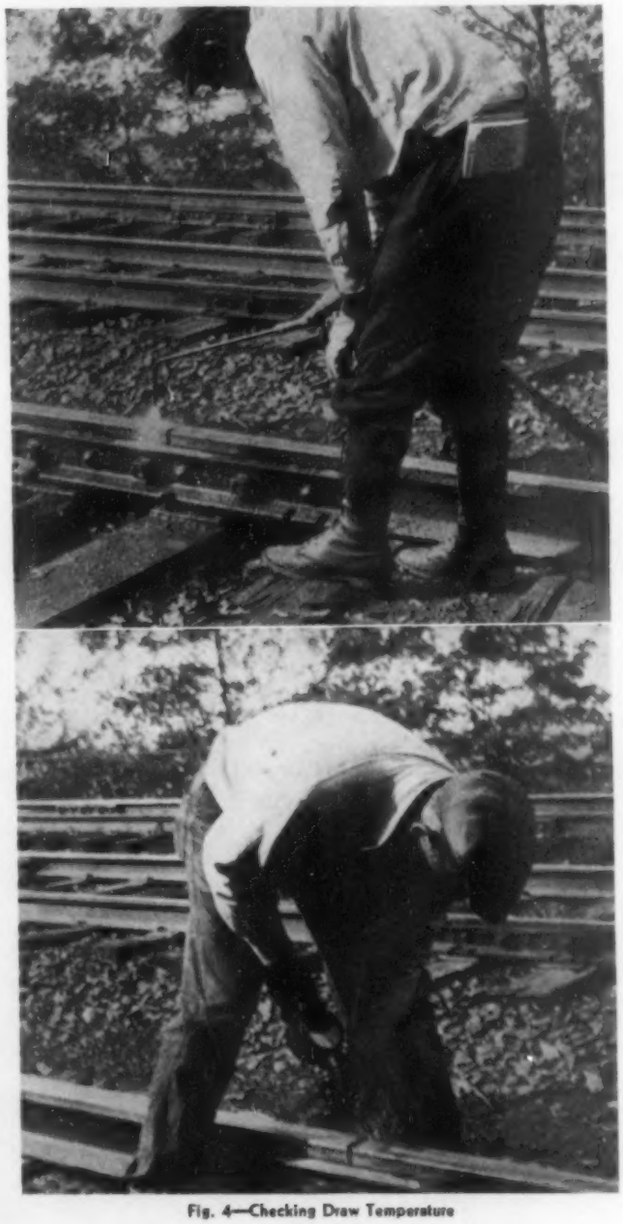


Fig. 4—Checking Draw Temperature

Fig. 5—Checking Temperature with Pyrometer before Quench is Applied

Fig. 6—Applying Water Quench

the reforming process in that the rail ends are brought up to surface by addition of metal.

This method also differs from puddle welding in that the surface of the rail is not broken down as in puddle welding, but instead a surface fusion technique is employed. The procedure in this operation is as follows:

1. The surface of the rail is heated quickly to a fusion temperature.
2. The adding metal is applied as soon as this surface fusion condition is observed, without puddling the metal. This permits a quicker start in the application of the adding material, results in less heat penetration and effects a considerable saving in oxygen and acetylene consumption on account of the speed of the application of the rod in this process.

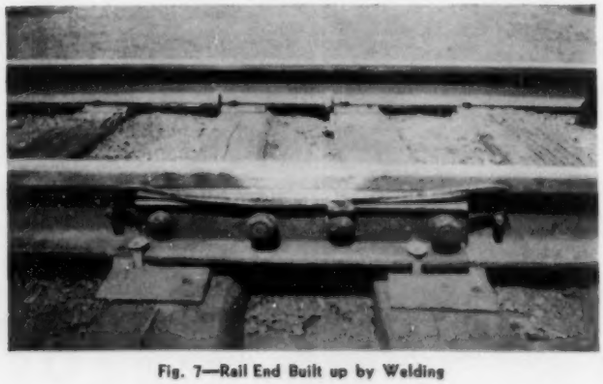


Fig. 7—Rail End Built up by Welding

The process is especially well adapted to building up rail ends when a ground joint is desired. With a little experience a welder can flow the adding material so smoothly and evenly that very little grinding or flatter work is required to make a finished surface.

In making a surface fusion weld on a rail end, a welder can carry a bead 2 inches or more wide without any difficulty, which is impracticable to do with the puddle weld. While it is possible to weld in this way with a single flame tip and effect a considerable saving over the puddle weld method, a new multi-flame tip has been developed to further increase the speed. A welder can make the flatter-finish welds on rail ends at the rate of 1 inch per minute without difficulty, using the multi-flame tip. For grinder finish, the rate of application of the adding material is even greater.

Combination Method

For out-of-face welding, a combination of surface fusion welding and reforming of rail ends is the most economical method of reconditioning rail. It is well known that all rails, in almost the identical service, do not develop the same degree of batter, and it is for this reason that both methods of reconditioning rail ends are recommended.

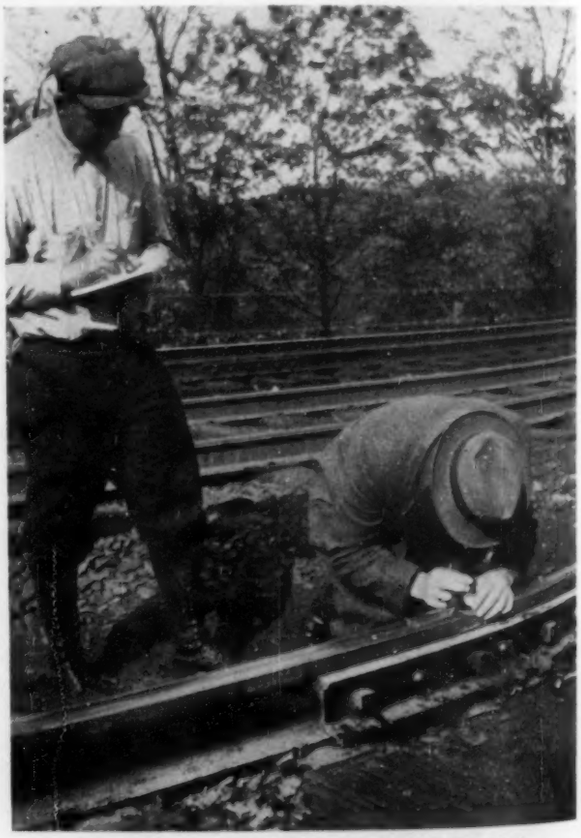


Fig. 8—Checking Brinnell Hardness on Heat-Treated Rail End

Preparatory Work

Regardless of the method used in building up or reconditioning rail ends, there is a certain amount of track work, such as surfacing joints, applying new or reformed joint bars where necessary, renewing poor joint ties, tightening all bolts and so forth, which should be done ahead of the welders to assure the best results.

Present Trend of Track Welding

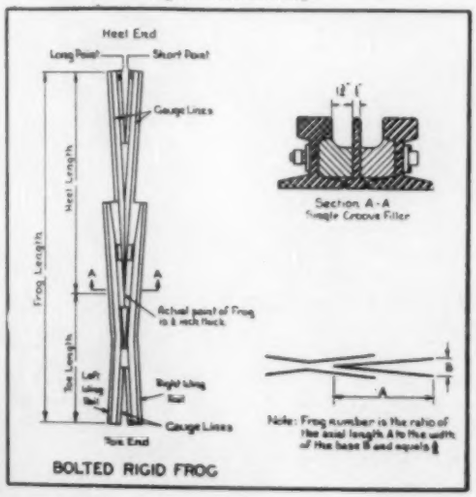
A committee of the American Railway Engineering Association on the subject of "Methods of Reconditioning

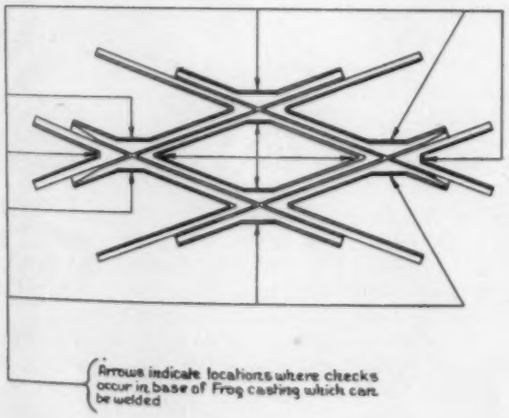
Rail Ends, Fastenings, Frogs and Switches in Track" a short time ago sent out a questionnaire to a number of railroads, and made a compilation of the return. The twenty-four railroads that reported to the committee are among the largest in the United States and Canada, and represent all sections of the country. Therefore, the information developed may be taken as fairly representative of the present trend of track welding. Some interesting facts deduced were as follows:

1. Of all the railroads reporting, 50 per cent use oxyacetylene welding only; two roads report arc welding only; and the remainder use both arc and gas welding.

2. During the year reported, approximately 85 per cent of all the joints built up were reconditioned by the oxyacetylene process.

Fig. 9—Turn out Frog





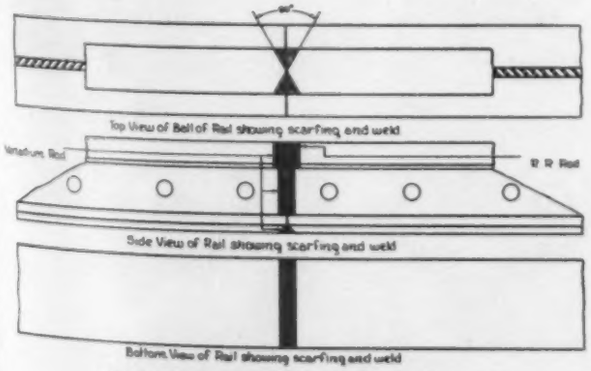
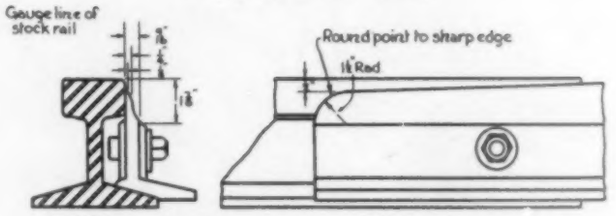

Top View of Bell of Rail showing scarfing and weld
Vertebra Rail
R R Rail
Side View of Rail showing scarfing and weld
Bottom View of Rail showing scarfing and weld

Fig. 10 (Center)—Cast Manganese Crossing Frog
Fig. 11—Butt Welding Rails

Fig. 12—Switch Point Welding



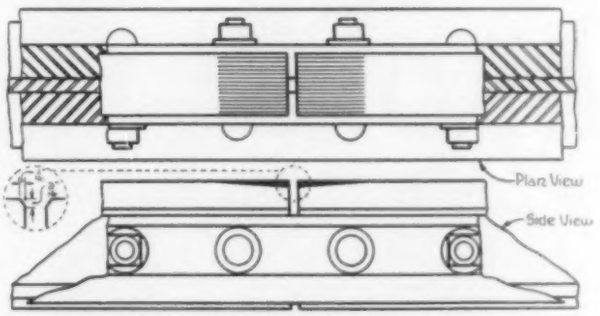


Fig. 13—Built up Rail End Showing Beveling

3. The amount of batter determining when welding should be done varies according to opinion, from $^1/_{32}$ inch to $^1/_8$ inch. However, the majority of the railroads reporting indicate that rail ends with batter $^3/_{64}$ inch require welding. It is obviously not good policy to let rail batter develop to the maximum permissible extent before welding. The cost of maintaining good surface where battered rail exists for a relatively short period is more than that of reconditioning the rail ends. Not only are maintenance costs reduced and the life of the rail materially extended, but it is a long step toward the goal all track maintenance men are striving for; that is, good riding and safe track.

4. For the year reported, the largest number of joints built up by a single railroad, using the electric process only, was 170,643. The largest number reported by a single railroad using the oxyacetylene process only was 229,103 joints. The largest number of joints welded by a single railroad reporting the use of both the arc and the oxyacetylene process was 297,079. Of these, 215,029 were welded by the oxyacetylene process and 82,050 by the arc process.

5. About 30 per cent of the roads using the oxyacetylene process report the use of grinding machines on some of the work. All using the electric process report using grinders, usually one grinder for each arc.

6. There seemed to be considerable variation in the cost of building up rail ends, depending primarily on the amount of batter and length of weld; also whether or not the rail ends are built up out-of-face or spot welded. The term "out-of-face" is used where work is done in a continuous stretch; while "spot welding" is welding a few joints in each mile.

Where welding of rail ends is done out-of-face a surface grinder is usually used instead of flatters for finishing the work. This practice results in a uniform surface and a saving in gases. One or more grinders are required to finish the work of six welders. Six welders will recondition 200 to 300 joints daily, the condition of the rail ends being the governing factor.

During the past few years the railroads have deferred the purchase of hundreds of thousands of tons of new rail, with a result that the practice of reconditioning of rail ends is an economic necessity, and is producing the desired results in the way of additional service life of rail and smooth riding track for high speed traffic.

Switch Point and Frog Welding

In addition to rail end welding the oxyacetylene process affords a very convenient and economical method of reconditioning and reclaiming frogs and switch points. This work can be done either in the track or in the shop. If the frogs and switch points are in good shape, that is, no loose bolts, rivets, etc., the work can be done more economically in the field. If new bolts, rivets, filler blocks, etc., are required it is better to do the work in a shop equipped for such repairs.

Heat Treating

While the process of heat treating rail ends is a more recent development in the application of the oxyacetylene process to rail maintenance, it has been in use sufficiently long to prove its effectiveness in preventing rail end batter. This is substantiated by the fact that several of the larger railway systems have accepted the process of heat treating rail ends as a standard practice and are now heat treating reconditioned rail ends, as well as new rail.

In the process of heat treating rail ends the pearlitic structure of the steel is changed to the tougher and harder sorbitic structure. This is accomplished by heating the ends of the rail quickly and uniformly with a torch, to a temperature of 1500° F., and then quenching with water to a temperature of 300° F. The ends of the rail are then reheated to a drawing temperature of 650° F. and allowed to cool.

An operator soon becomes very proficient in determining the quenching temperature by the heat color of the rail. Too much should not be left to the eye, however. A pyrometer should be used to determine the quenching and drawing temperature, especially until the operator has had considerable experience and is sure his judgment is correct. Even then the pyrometer should be used frequently as a check.

The drawing temperature is easily checked by striking a piece of 50–50 solder across the rail end. If the solder melts freely and oxidizes slightly in a few seconds, causing it to become a straw color or have a purple tinge, sufficient heat has been applied. If the solder remains bright more heat is required.

The accompanying graph (Fig. 1) shows plainly the effect of heat treatment of rail ends to prevent batter.

The rail in question has been in service four years and has carried over 200 million gross tons traffic. In order to get a direct comparison of the effect of heat treatment alternate joints in the track were treated.

(NOTE. This graph was taken from a current bulletin of the American Railway Engineering Association.)

Bridge Repairs

It has been necessary to reinforce many existing steel structures to take care of the heavier rolling stock. Welding has made it possible to do this easily and economically by welding on additional plates, angles, etc., as necessary.

Material for such repair is readily cut to size in the field with the cutting torch. In the demolition of old structures the cutting torch is indispensable.

Pipe Welding

The water service and plumbing departments have found the welding and cutting torch very useful tools, both in repairs to existing pipe lines and the installation of new lines.

On a welded pipe line no expensive fittings are required. When a connection is desired all that is necessary to do is to cut a hole in the line and weld on the connection. Pipe templets for various size pipe and connections are available.

In the installation of steam lines expansion and contraction loops of practically any desired shape or size can be quickly fabricated on the job from standard welding fittings and straight lengths of pipe. Such loops are uniform in wall thickness and strength. There is no reduction of cross-sectional area and consequently no added resistance to flow. Aside from this, welded loops can be formed to fit neatly into the available space, and are assembled to the rest of the piping with the same smooth joint which characterizes all welded connections. Welded steam lines are more easily insulated and make a much neater appearing job.

In welded pipe line installations full use of bended pipes can be had, thus eliminating many fittings. The smaller sized pipes can be bent cold and the larger sizes heated with an oxyacetylene flame quickly and bent as desired.

The elimination of threaded connections in air, gas, steam and water lines in yards and terminals eliminate the source of a great deal of trouble and affects a considerable saving for every screw joint is a potential source of trouble.

Especially is this true in lines supplying air in cripple track when many air tools are used. A number of small leaks or a few large ones will so reduce the effective air pressure as to cause delays and poor tool operation. This is a direct loss of time and labor.

Track Bonding

The most essential thing in automatic signaling and train control is a good electrical circuit in the track. If the bonding is poor, trains will be delayed and battery consumptions will be excessive.

The wire-pin connected bond was used exclusively in bonding rails for automatic train signaling until a few years ago. Now the fusion bond is rapidly replacing the wire bond.

The welded bond is shorter than the wire bond and hence gives greater protection. With a wire bond a rail could be broken at the end of the angle bars or the whole head of the rail could be broken out within the limits of the angle bar and yet the track circuit would be intact and a clear signal indication given. With the welded bond applied on the head and at the very ends of the rail complete protection is afforded.

A considerable saving is also affected in battery consumption by the fusion bond, due to the low resistance of the welded bond.

Conclusion

There are many other operations involving the use of the oxyacetylene torch in the maintenance of way and signal departments, such as butt welding of rails, repairs to motor cars, track, tools, switch stands, interlocking plants and so forth. All of these operations save the railroads considerable expense but time will not permit a detailed description of them.

Welding—A Handy Tool

By A. F. DAVIS†

New 121-Mile Gas Pipe Line Completed by Arc Welding

STEEL pipe, fabricated by electric welding and joined in the field by the electric arc, was used in construction of a new 121-mile gas pipe line just completed from Clayton, Wyoming, to Scottsbluff, Nebraska, for the North Central Gas Company.

The new line consists of 65 miles of 12-inch pipe and 56 miles of 10-inch. The pipe was supplied in random lengths of 20 to 40 feet. Ends were beveled approximately 35 degrees.

The usual procedure was followed in welding the line. The pipe was lined up in 80- and 120-foot sections. Joints were plain end type with backing up ring or chill band. Welds were made in two beads, the first with $^1/_4$-inch electrodes, the finish bead with $^5/_{16}$-inch. The welding was done at the rate of 9 minutes per weld by the welding gang which consisted of one tacker and three welders. Weld strength and ductility was checked by pull and bend tests of coupons. The line was tested for leaks every four or five miles with 50 pounds air pressure. The 121 miles were completed in 77 working days. All welding was done by H. C. Price, Inc., Bartlesville, Oklahoma, with shielded arc electrodes. Williams Bros. Inc., Tulsa, Oklahoma, were the general contractors.

Arc-Welded Ore Jigs Flown 60 Miles into New Guinea

Two modern developments, the airplane and the electric arc process of welding, enabled delivery of 20 mineral separation jigs from the coast of New Guinea across a range of mountains to the dredge location, 60 miles inland. Planes provided transportation, the electric arc provided minimum weight. The jigs were manufactured by the Ozark Engineering Company, Joplin, Missouri, to the design of F. N. Bendelari, the inventor.

† Vice-President, The Lincoln Electric Company.

Fig. 1—Welding the New 121-Mile North Central Gas Company Pipe Line with the Shielded Arc Process of Electric Welding

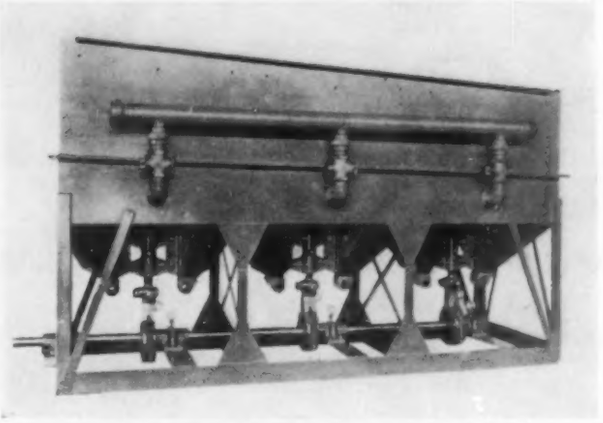


Fig. 2—Twenty Ore Jigs Like This One Were Flown 60 Miles into the Interior of New Guinea by Airplane. Minimum Weight Was Provided by Arc-Welded Construction. It Is a 42-Inch 3-Cell Standard Type Ore Jig, 10 Feet Long, 4 Feet Wide and 7 Feet High. Built by Ozark Engineering Company, Joplin, Mo., by Arc Welding

These mining jigs are used for many different mineral separations. The material worked varies from 1-inch gravel for concrete aggregate to the gold saved by jigs on gold dredges. Lead, zinc, scheelite, magnetic tin and manganese ores are also concentrated by this equipment.

The jig illustrated in Fig. 2 is 42-inch 3-cell placer type, 10 feet long, 4 feet wide and 7 feet high. It is welded of $^5/_{16}$-inch steel plate and weighs 6100 pounds. Another type is the 42-inch 3-cell standard type ore jig. This type is identical in over-all dimensions to the placer type but is constructed of $^3/_8$-inch plate, and weighs 8750 pounds. Only by welding was it possible to provide low weight without sacrifice of strength.

The arc-welded construction of the jigs illustrated utilizes standard rolled steel plate and shapes. These materials were merely cut to exact size and welded together into one integral unit with the electric arc.

The jig bases consist of standard mill shapes. The two longitudinal members and six bearing supporting members are of equal size. End crosspieces are channels. The upright members are standard angles.

Arc welding, in addition to providing minimum weight, permitted considerable savings in time and cost of construction. No time was required in drilling or punching parts since the electric arc joined steel to steel without use of intermediate connecting members. This simplified construction, reduced detailing, laying out, handling and assembling.

In loading the units into planes, each jig was lifted by derrick at the landing field and lowered through a

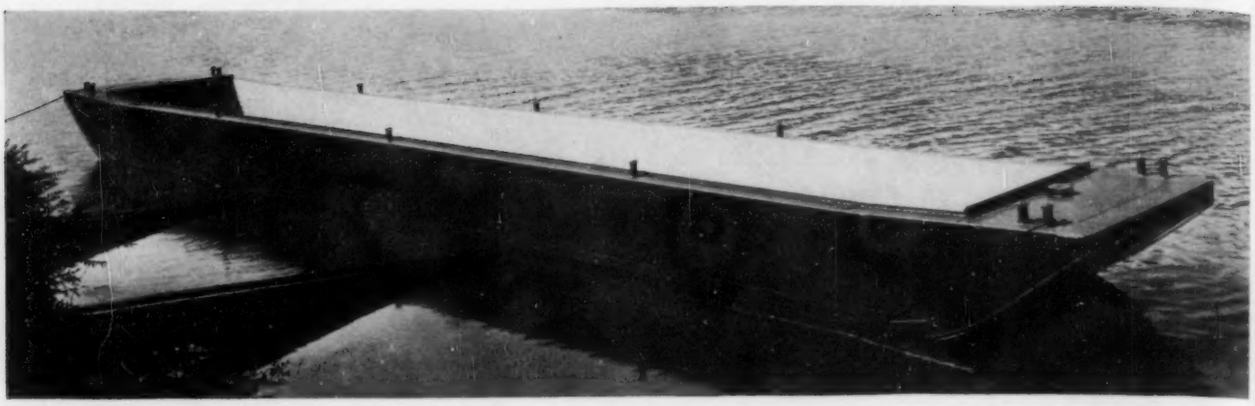


Fig. 3—Standard Type Coal Barge, 175 Feet Long, 26 Feet Beam, 10 Feet 8 Inches Depth, Built by The Dravo Contracting Company, Pittsburgh, Penna., Entirely of Steel Arc-Welded

hatch provided in the top of the plane. One jig was carried at a time. The distance flown was 60 miles and the altitude attained was between 6000 and 8000 feet depending on weather conditions in crossing a range of mountains.

Arc-Welded Barge Pulls Orders for Ohio River Builder

Barge line operators on the Ohio River are showing great interest in a new coal barge constructed by The Dravo Contracting Company, Pittsburgh, Penna.

The new all-welded steel coal carrier (see Fig. 3) is 175 feet long over-all, 26 feet beam and 10 feet 8 inches deep. Its capacity, fully loaded, is 850 to 1000 short tons. The draft light is 1 foot $3^1/_4$ inches.

The hull transverse framing and rake frames are of special design developed by the builder to provide maximum strength.

The welding method and procedure was carefully planned and required extensive and accurate shop fabrication; also sub-assemblies of various units as a part of the shop fabrication.

The procedure was planned so as to obtain a maximum amount of position welding for all assemblies. Special equipment for position welding was employed in the shop. Accurate shop assembly was obtained by special jigs and assembly machines.

Electric Arc Used to Write Epitaph

Rising out of the Arizona desert this monument perpetuates the name of the man who drove the only camel caravan ever to trek this land.

In Greek, the man's name was Phillip Tedro; in Arabic, Hadji Ali. But in the lingo of his friend the American soldier, Phillip Tedro alias Hadji Ali, was just plain "Hi Jolly."

There was magic in the way Hi Jolly handled his magestic charges. And Hi Jolly, had he been alive at the time, would have seen magic in the "pen" which,

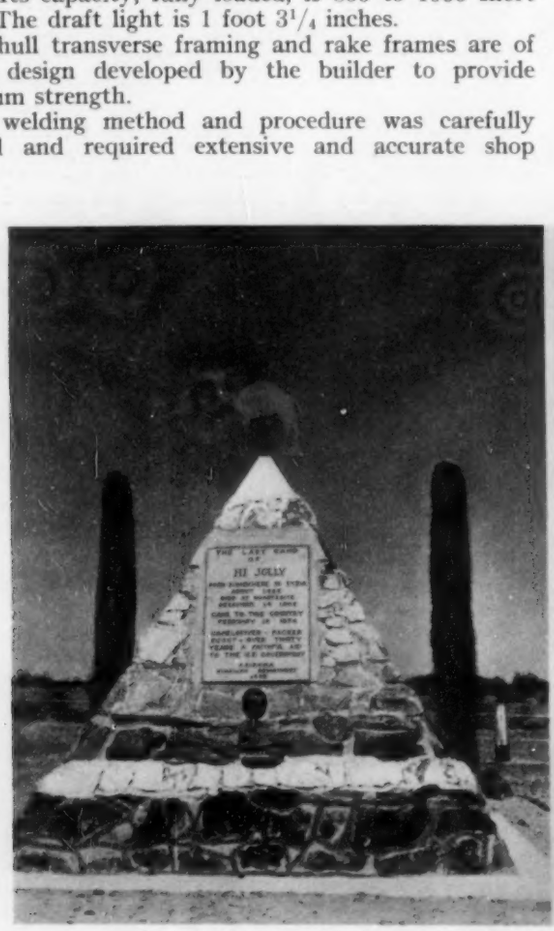


Fig. 4

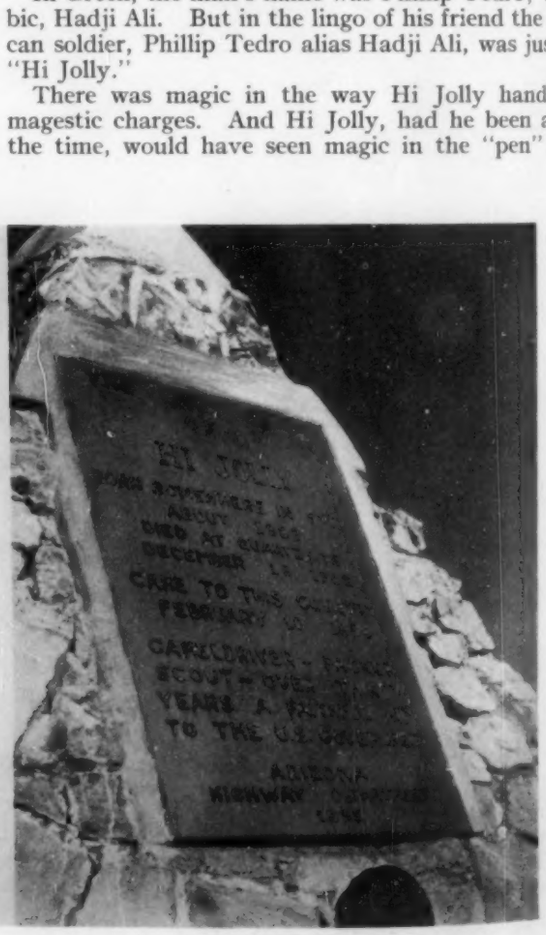


Fig. 5

Fig. 6—Eighteen 5000-Barrel Storage Tanks Built in One Month by The National Tank & Mfg. Co., Los Angeles, for the Wilshire Oil Company's New Santa Fe Springs, Calif., Refinery. Tanks Are Entirely Arc Welded

with a sizzling hiss and an eerie bluish white light, wrote his epitaph with molten steel. The "pen" used to letter the steel tablet was the electric arc.

Eighteen 5000-Barrel Storage Tanks Are Built in One Month

Unusually fast construction of storage tanks was noted recently when eighteen 5000-barrel units were built complete in one month at Santa Fe Springs, Calif. The tanks were built by The National Tank and Manufacturing Co., Los Angeles, for the Wilshire Oil Company at its new Santa Fe Springs refinery.

The tanks are identical in size and construction. They are 30 feet high and 35 feet in diameter. Thickness of plate is $^1/_4$ inch in bottoms and bottom rings, $^5/_{16}$ inch in sides and covers.

Fast erection was made possible by simplified arc-welded construction. The tanks are simply pieces of steel plate cut and formed, then welded together into an integral unit without use of intermediate connecting members. Approximately 3000 feet of welding was required in each tank. All welds were plain butt type and all welding was done by the shielded arc process.

In addition to permitting fast erection, the use of arc welding greatly simplified fabrication of the steel. Elimination of connecting members reduced detailing and entirely eliminated punching and drilling.

The tanks were engineered and constructed by The National Tank and Manufacturing Co., with the welding engineering assistance of C. O. Conzett, Los, Angeles office, The Lincoln Electric Company.

Arc welding is also being used in construction of the refinery equipment. (See Fig. 7.) The pressure equipment, built by The Southwestern Engineering Co., Los Angeles, is arc welded. Two 125-foot stacks—one erected by The Buehler Tank Co., the other by Western Pipe & Steel Co.—are one-piece all-welded construction. Piping and miscellaneous structural steelwork is being erected by the general contractor, the Ralph M. Parsons Co., Norwalk, Ohio.

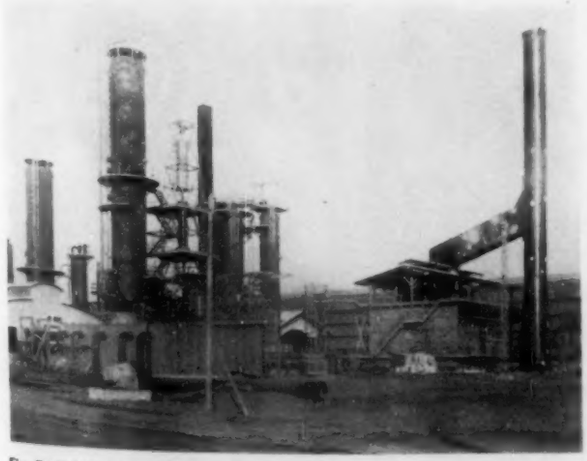


Fig. 7—Bubble Towers, Stacks, Piping Structural Steel, Etc., Practically All Arc Welded

Construction of the new refinery began last July and is expected to be completed in April.

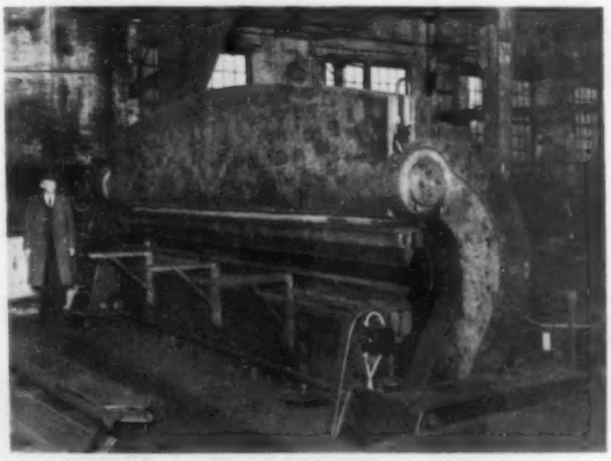


Fig. 8—World's Largest Steel Press Brake, 500 Tons Capacity, Capable of Bending Materials 16 Feet Long, All Arc-Welded Construction

New All-Welded Press Brake Announced

A 500-ton capacity steel press brake, said to be one of the largest of its type ever manufactured, and capable of bending materials 16 feet long, is announced by the Boom Boiler and Welding Company, Cleveland, Ohio.

Revolutionary in design, the Boom brake (see Fig. 8) pulls two leaves together instead of merely pushing one leaf down. This eliminates approximately 30 per cent in material and permits easy adjustment for bending by raising or lowering the bottom leaf which is moved by worm drive controlled by a switch mounted on the front of the machine. Different, also, from conventional prac-

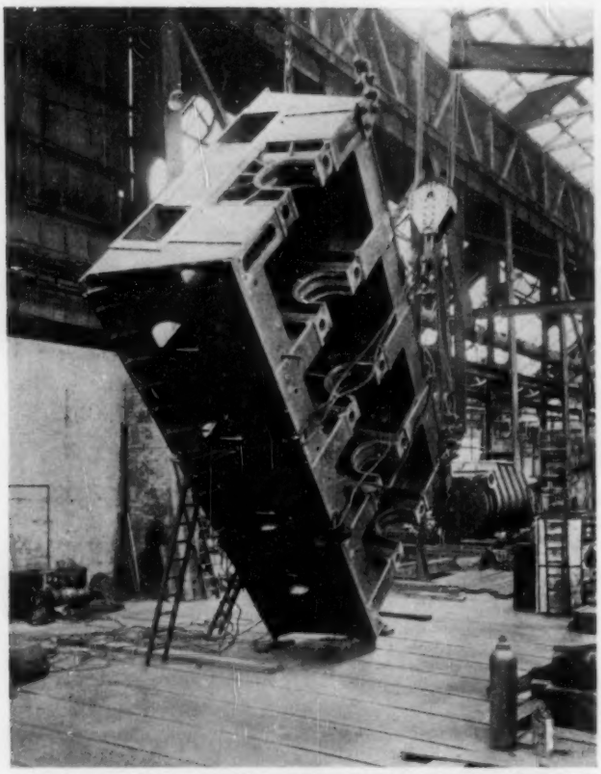


Fig. 9—Arc-Welded Steel Bedplate of New Diesel Engine Which Has Double the Power Yet Is No Larger Than the Unit It Replaces in a Motorship

tice all driving mechanism, adjustment shafts, etc., are below floor level, leaving the entire top clear and eliminating danger resulting from possible overhead breakage.

The new brake is 24 feet 2 inches extreme length, 16 feet 1 inch long between housings, 7 feet 1 inch wide, 9 feet 11 inches extreme height and 6 feet 9 inches high above the floor. The weight is 61 tons.

The two leaves of the brake are 17 feet 7 inches long, 4 feet high, 10 inches thick and weigh 8 tons.

Links are 8 feet 3 inches long over-all, 8 inches thick and 3 feet 4 inches wide from drive center to the link's outside.

Bending members are of high carbon steel, machined to meet bending requirements.

Housings, both inner and outer, are 6 feet 8 inches long. Inner is 8 feet 11 inches high, outer 3 feet.

Construction is entirely of steel, arc welded. Not a single casting is used. Providing maximum rigidity per minimum pound of weight, arc-welded steel construction permitted 30 days' saving in time and $2200 in cost through elimination of patterns and pattern drawings. Machining costs were said to be $1500 less than would be the case with castings.

According to the manufacturer, the building of a machine so large would not be practical with cast-iron construction. To obtain equal rigidity in ribs and flanges with cast iron, weight would be increased by more than 100 per cent. All welding was done by the shielded arc process.

Power for operating the brake is furnished by a 30 horsepower electric motor in conjunction with a 2-ton flywheel and transmitted by V-belts to gears and shafting. Operation is two-speed—4 or 20 strokes per minute.

New Diesel Engine

What is probably one of the greatest forward steps in the diesel engine since its invention was noted recently in England when a new engine, built to replace a unit in a motorship, doubled the power of the vessel yet required no more space than the original unit.

The new engine is rated 4000 brake horsepower at 109 revolutions per minute but actually develops 4400 brake horsepower. Of the double-acting two-stroke four-cylinder type, the new diesel has a bore of $27^1/_2$ inches and stroke of $47^1/_2$ inches. It was built by Richardsons, Westgarth and Company for the motorship Silverlarch of the Silver Line. The Silverlarch is one of two vessels which the owners are having reconstructed by J. L. Thompson and Sons, Sunderland, England, to provide increased speed.

Construction of an engine having such a high ratio of power to size has been made possible by improved design employing steel and electric welding. Major parts such as bedplate and columns, as well as scavenging air main, crankcase covers and plates and exhaust pipe, are all built of arc-welded steel plate. The use of arc

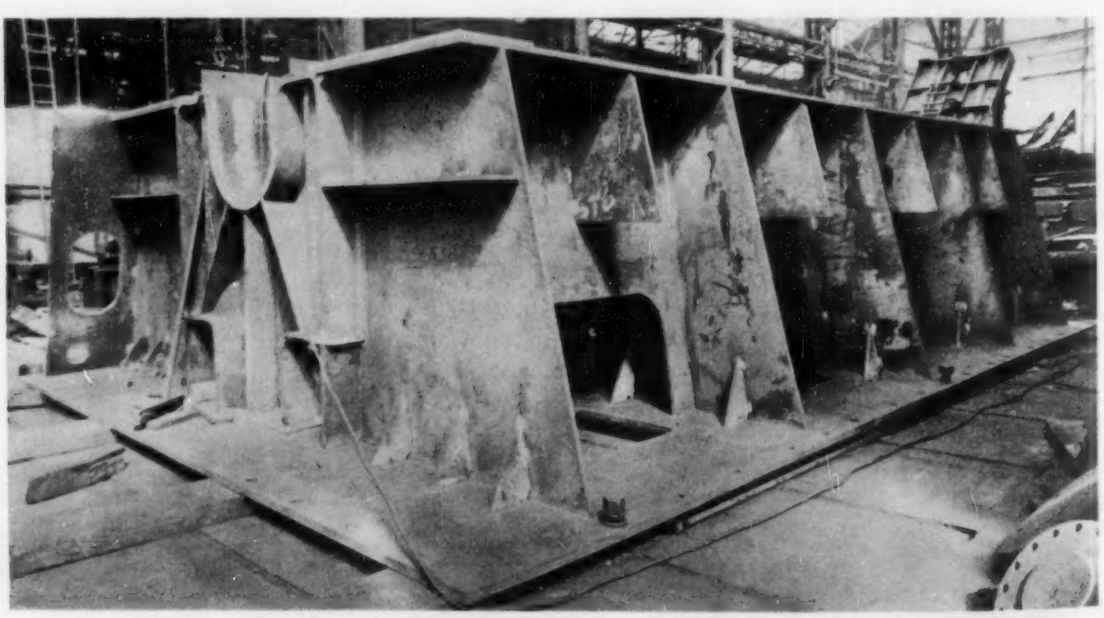


Fig. 10—Bedplate of New 4000 Horsepower Diesel Engine before Applying Side and End Plates. Arc Welding Permitted 33% Savings in Weight

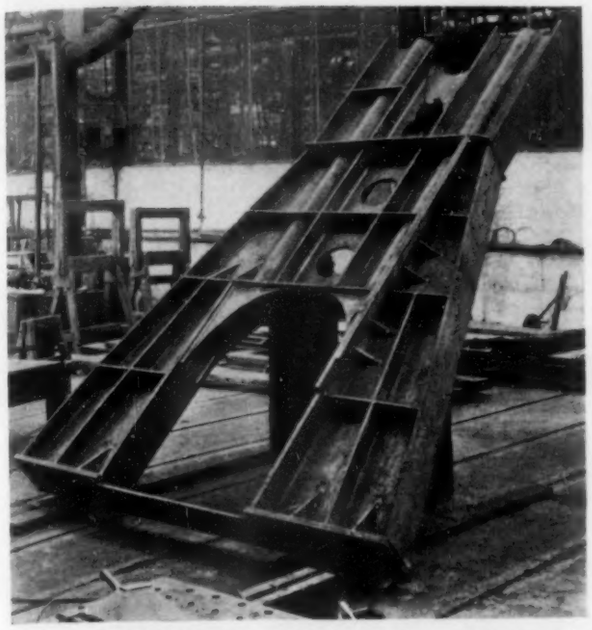


Fig. 11—One of the Main Columns, Built Entirely of Arc-Welded Steel for New 4000 Horsepower Diesel Engine Recently Completed in England

welded steel provided maximum strength and rigidity per minimum size of members and minimum pound of weight. This advantage enabled the builder to obtain a structure double the capacity possible with a suitable form of cast-iron construction.

The bedplate (see Figs. 9 and 10) is of special interest in view of the engine's power and its comparatively low speed. The length of the bedplate is 22 feet 6 inches, width 14 feet and depth 5 feet 4 inches. It is of the tank-top type.

The bottom plate consists of two lengths of steel plate double butt-welded together longitudinally. To obtain maximum rigidity, the sump is welded integral with the bedplate.

Construction of one of the main columns is shown in Fig. 11. The columns consist of a minimum number of pieces of steel plate fused into one integral unit by the electric arc.

The cast steel bearing housings are fixed in the bedplate by steel plates welded to them and to the sides and bottom of the bedplate.

All welds in construction were made in two passes. In the case of the butt welds, the first pass was made with $^1/_4$-inch electrodes, the second with $^5/_{16}$-inch. For the other welds, $^3/_{16}$-inch and $^1/_4$-inch electrodes were used. The welding was done by the shielded arc process.

Although the aim of the builder was to obtain a structure of maximum rigidity at moderate cost without any particular emphasis on lightness, the saving in weight was large. The bedplate weighs approximately 33% less than would be possible with suitable cast-iron construction. Actual weight, arc welded, is $29^1/_2$ tons. Weight, in cast iron, would have been 44 tons. Cost savings were also considerable due to elimination of patterns and pattern drawings and to simplified machining.

The new engine was designed by W. S. Burn representing the builders and recently underwent test-bed trials.

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(*Continued on page 33*)

Low-Alloy, High-Tensile Steels*

By A. B. KINZEL†

ONE of the most interesting developments in metallurgy during the past year has been that of low-alloy, high-tensile steels of a type suitable for fabrication in the as-rolled condition. Broadly speaking, such steels are not new as witnessed by the Eads Bridge constructed in 1874 of metal supplied by the Chrome-Steel Company, the silicon steel in the *Mauretania*, the time-honored nickel steels in many bridges, and the medium-manganese steel in the Kill Van Kull Bridge, as well as a great many other applications. Most of the above-mentioned steels have strengths of at least 85,000 lb. per sq. in. and 0.20 per cent or more carbon.

The newer types may be distinguished from the older, mainly in that the carbon content runs from 0.20 per cent down and in addition they contain other alloying elements to improve either the mechanical characteristics or the corrosion resistance, or both. This may be stated in another way—namely, that in the newer types of steels an increasing importance has been placed on ductility, weldability and corrosion resistance.

Ductility and Uniformity Desirable

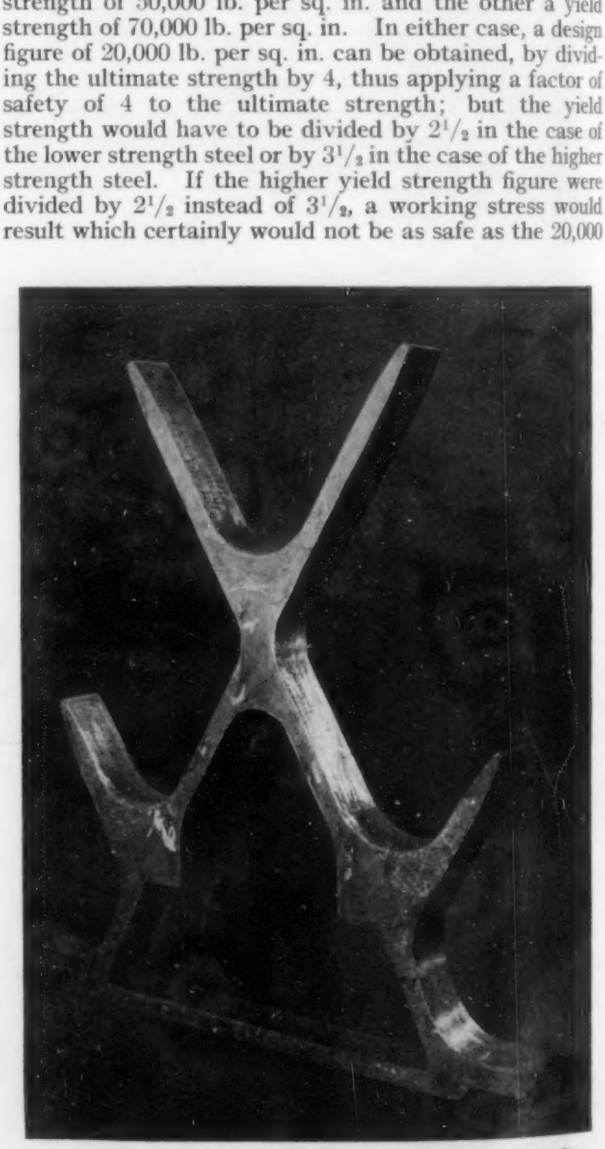
The characteristics desired in a high-strength, mild-alloy steel may be reviewed with profit. Higher ultimate strength obviously is the first criterion. With this, however, it is necessary that there be sufficient ductility for fabricating purposes and sufficient lack of sensitivity to minor variations in rolling conditions, rates of cooling and types of cooling from the welding operation, so that difficulties on these scores will not be encountered and the finished structure will—locally as well as generally—contain steel having the desired ductility as well as strength.

Design Fiber Stress Determination

To take advantage of the improved properties, the engineer uses a higher design stress. For the last century or more, the engineering profession has arrived at this figure by dividing the tensile strength of the material by a factor of safety. In this factor of safety, allowance is made for the combination of ignorance as to the properties of the steel, ignorance of exact stresses in the structure, ignorance as to service overloads on the structure, and ignorance as to uniformity of the materials and their behavior under special stress conditions. Gradually, as we learn more about steel and the properties to be measured and considered in our structures, the various factors of ignorance with regard to the material are being reduced.

Yield strength and ultimate strength are two of the first properties to consider in determining a suitable factor of safety. In the design of a column, for instance, yield strength is very important because it is probably the determining factor with respect to possible ultimate failure. On the other hand, in applications where failure might be due to repetitive stresses induced either directly or by vibration, we are less interested in yield strength than in the fatigue limit, which is a direct function of the ultimate strength. The ultimate strength in this case is the controlling factor. It matters little by which of several alternative methods a final design figure is obtained, provided that this figure in itself is high enough to utilize best the properties of the materials and still result in a safe structure—one that can stand any local overloading or general overloading to which it may be subjected in service.

Experience over many years has shown that a factor of safety applied to the ultimate strength results in safe structures. Of two steels each having an ultimate strength of 80,000 lb. per sq. in. one may have a yield strength of 50,000 lb. per sq. in. and the other a yield strength of 70,000 lb. per sq. in. In either case, a design figure of 20,000 lb. per sq. in. can be obtained, by dividing the ultimate strength by 4, thus applying a factor of safety of 4 to the ultimate strength; but the yield strength would have to be divided by $2^1/_2$ in the case of the lower strength steel or by $3^1/_2$ in the case of the higher strength steel. If the higher yield strength figure were divided by $2^1/_2$ instead of $3^1/_2$, a working stress would result which certainly would not be as safe as the 20,000



Flame-Cut Chromium Type Steel Frame of Crankcase for a 1000-Hp Twin-Six Diesel Engine

* Presented before the New York Section of the AMERICAN WELDING SOCIETY, March 10, 1936.

† Chief Metallurgist, Union Carbide and Carbon Research Laboratories, Inc.

lb. per sq. in. value arrived at by the more conventional method.

The possibility of having too high a ratio of yield strength to tensile strength should also be considered, especially when a member is subjected to a two- or three-dimensional stress. This applies particularly to ratios in excess of those current in the high-strength low-alloy steels developed in the last few years. The measurement of ductility is normally carried out in single-dimensional stress; but when a member is subjected to two- or three-dimensional stress, the effective yield strength is increased. Poisson's ratio approximates 0.3 for steel. This means that an equivalent two-dimensional stress effect would result in an apparent increase in tensional stress of about one-third. As long as the effective yield strength is increased to a point below the ultimate strength, plastic deformation can take place before failure. If, however, the increase in effective yield strength due to the two- or three-dimensional effect is such that the yield strength reaches the ultimate strength, the structure will fail at the effective yield point without plastic deformation. Thus, there is reason to maintain a definite spread between yield strength and ultimate strength, lest the ductility of the steel fail to play its rôle in a given type of service. Were structures actually stressed in service to a point approximating the relatively high yield strength of some of the newly envisaged steels, the situation might well be viewed with alarm. Knowledge of service conditions, however, and the factor of safety, which is present because of limitations both of the material and of the design, redeem the situation.

To sum up this matter of choosing a design fiber stress, most engineers today agree that it is necessary to consider each of the various properties of the steel.

Alloys for Uniform Strength and Ductility

Ductility is essential for a great many purposes, not only in ordinary fabrication in steel mills but also later in the shop where the steel must be formed successfully and worked into the final structure with the optimum results.

Steel manufactured in the mill on large-scale production is cooled as soon as it comes from rolls. For most economical production and particularly where large masses are involved, further heat-treatment is practically out of the question; that is, the steel must be used as-rolled. As-rolled steel should be relatively uniform notwithstanding the variations in finishing temperature and in rates of cooling that are encountered in shop practice. This means that the steels should be so alloyed that they will respond within the limits desired.

Although added strength can be obtained by increasing the carbon content, this would give strength at the sacrifice of ductility and further increase the sensitiveness of steels to mill conditions. Another way to increase the strength is to lower the carbon content and use alloying ingredients. This is the way of the new alloy steels.

Fe–C–O

I II III Chart Showing Elements

Cr Si Mn Use in Low-Alloy
V Al Ni
Mo Cu High-Tensile Steels

P S

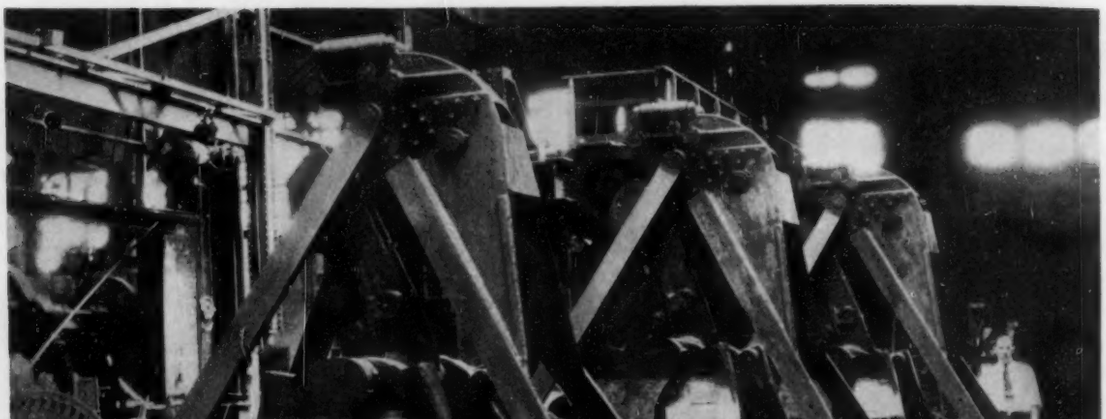
Of the alloying ingredients shown in the accompanying chart, the elements Fe–C–O, iron, carbon and oxygen, may be considered as the base of our modern steels. As long as steel is manufactured by present or analogous processes, oxygen is going to be a factor. Phosphorus and sulphur are also present in the base. The elements largely used in the low-alloy steels manufactured today divide rather naturally into three groups:

The first group contains the carbide formers, the second group the deoxidizers, and the third group the austenite formers. The elements in the first two groups are also alpha formers; that is, if these are present in sufficient quantity iron will not transform at any temperature and accordingly any heat-treatment is ineffective from the standpoint of hardening. Only the grain size might be affected. This alpha-forming tendency means that these elements are primarily soluble in ferrite. Because these elements are readily soluble in ferrite, their strengthening effect is twofold: first, their effect on the critical temperature, particularly with varying rates of cooling, and second, their effect in the ferrite matrix—the base of the steel, so to say.

The elements in Group I raise the critical temperature a very small amount, on heating, but on cooling at moderately rapid rates they markedly depress this transformation temperature. If present in the right amount in relation to carbon and other elements, the elements of Group I lower this critical temperature to such a point that the final structure is fine pearlite. Fine pearlite means high strength in the range under consideration. Not only will Group I elements produce this result, but silicon and the austenite formers likewise act in this direction; that is, the strength can be obtained with any one or any combination of the above elements. The austenite formers depress the critical point in two ways, but that is not important for our purposes. That the critical point is so depressed is the important factor. It means that strength is achieved with low carbon content, and thus ductility of a high order of magnitude. Broadly speaking, a 70,000 lb. per sq. in. low-alloy steel has the same ductility as the 45,000 lb. per sq. in. ordinary carbon steel, and a 90,000 lb. per sq. in. low-alloy steel has the same ductility as the 55,000 lb. per sq. in. standard boiler plate. This shows the advance that has been made by the low-alloy steels.

Classification of New Alloy Steels

The new alloy steels may be divided into three categories depending upon the main alloying element used to get the increased strength as follows: chromium steels, nickel steels and manganese steels. There are several well-known types of chromium steels, among which the two best known in the United States are the ones containing 0.50 per cent chromium with 0.75 per cent silicon and 1.25 per cent manganese with or without copper, and the second containing 1 per cent chromium, 0.75 per cent silicon and 0.50 per cent manganese, generally with copper and phosphorus. The carbon content of these steels is such that more of the carbide-forming element is present than necessary to satisfy the carbon, and strengthening of the steel results by means of solution in the ferrite as well as by finer, better-dispersed carbides. Because of the presence of chromium in the ferrite of these steels, there is no sharp differentiation from steels strengthened with non-carbide forming elements, although some metallurgists have emphasized such a distinction. Silicon renders the steel relatively insensitive to minor variations in the final rolling temperature and hot bed cooling conditions. Further characteristics of the steels with respect to weldability will be discussed later, together with those of the other two groups.



Some 4-Yd. Clamshell Buckets Used on Underwater Dredging Operations for Caisson Foundations of the San Francisco-Oakland Bay Bridge. The Dredging Operations Were Carried on 200 Ft. Underwater. As the Total Weight of Each Bucket Was Not to Exceed 15,000 Lb., Chromium Type Steel Was Used for Corner Bars, Which Are Welded to the Head Frame

The second group in question contains from 0.50 to 2 per cent nickel and almost always from 0.50 to 1.50 per cent copper. Both the nickel and the copper are found in the ferrite grains in solid solution, with the exception that precipitation of the copper may be achieved by suitable heat-treatment. This steel, too, is relatively insensitive to variations in mill operations. Modifications of the nickel steel include the use of molybdenum in quantities approximating 0.20 per cent and occasionally high silicon.

In the third group—the medium-manganese steels—the manganese is distributed between the carbides and the ferrite and the desired strengthening effect achieved. In general, these steels are peculiarly sensitive to mill conditions which must be either very carefully controlled or the steels given a normalizing treatment after rolling. The addition of molybdenum has been used to strengthen these steels further. The use of vanadium, however, renders the steels highly insensitive, and results in an order of uniformity and ductility in the as-rolled material equivalent to those of steels in the first two groups. Another modification of the medium-manganese steels, one which is not known in this country but has been used considerably abroad, is the 1.50 per cent manganese steel with 0.50 per cent copper. Here again, the steel is quite sensitive to finishing conditions. Broadly speaking, the manganese-vanadium steel is the only one in this group which from the standpoint of fabrication may be placed in the same category as the best of the chromium and nickel steels mentioned above.

Influence of Carbon on Ductility

Most of the steels in question are made in two carbon grades—namely, one with max. 0.14 per cent carbon or lower, and the second with carbon ranging from 0.18 to 0.23 per cent. Combined with this insensitivity to cooling rates, the lower carbon steels possess a high order of ductility so that in sheet form they may be readily pressed and formed. This ductility also serves a very useful purpose in the welded structures, in that it permits sufficient plastic deformation so that residual stresses are reduced to a minimum in the welding of any given structure. In order to achieve this ductility the carbon must remain at or below the 0.14 per cent limit quoted above, and with the alloying contents in question this automatically limits the ultimate strength to approximately 80,000 lb. per sq. in. or less. It is significant that in European practice, construction has been restricted to steels having an ultimate strength of 73,000 lb. per sq. in., the thought being that more field experience is necessary before the higher strength can be used with assurance.

All three types of low-alloy steels have approximately the same ultimate strength for the same carbon content—that is, for balanced steels the ultimate strength is independent of the type of alloy ingredients, nickel-copper, manganese-vanadium or chromium-silicon. With properly balanced amounts of the alloying constituents, the ultimate strength and ductility are a function of the carbon content and are relatively independent of the particular alloy combination used. This is probably fixed by the nature of the austenite-pearlite transformation. In each of the steels in question the transformation takes place at the same temperature and at approximately the same speed for a given rate of cooling, and the strengthening effect by solid solution is approximately of the same order of magnitude.

With higher carbon contents, deviations from the above may be expected, but even at the carbon content generally selected for the second level—namely, 0.18 to 0.23 per cent, the ultimate strength achieved with properly balanced alloying constituents, as well as the corresponding ductility still shows no great difference in the three groups mentioned. In this carbon range an ultimate strength of 90,000 to 100,000 lb. per sq. in. is usual.

Weldability from the Engineering Standpoint

The most important other factor from the standpoint of manufacturing industry today is the matter of weld-

ability, not in the narrow sense of mere ability to make a good weld free from inclusions and blow-holes but rather in the broad sense, the ability to make a joint satisfactory for engineering purposes. The amount of alloy present in the steels just described is such as to give no great difficulty from blow-holes and inclusions to any one experienced in the art. That, therefore, is not a factor to be considered seriously.

The effect of the heat of welding on the metal adjacent to the weld must, however, be given attention. Immediately next to the weld there is a zone which has been in the mushy stage, between liquidus and solidus temperature. Immediately back of this there is a zone that has been subjected to temperatures in excess of those normally recommended for heat-treatment. The next zone contains material subjected to the usual normalizing or hardening temperature, and beyond that is material actually in the critical range. Still further from the weld is a zone which has been subjected to a sub-critical annealing temperature, which if held long enough would result in a spheroidal structure.

As far as the mushy zone is concerned, the only matter of concern in alloy steels is segregation of the constituents. Metallurgists have long appreciated this, and naturally have so chosen their alloying additions as to avoid serious effects due to this phenomenon.

The next zone is that of rapid grain growth. If the temperature of this zone is maintained long enough, excessively large grains might result, but the time of welding is usually so short that this is not a matter of concern.

The zone subjected to normalizing temperature, and also the high temperature zone, do, however, require further consideration. As the welding operation progresses, the material in the normalizing zone is heated well into the austenite range, but is then quenched by transfer of heat into the cold mass of metal. A very drastic heat-treatment results.

The new low-alloy steels with their carbon content below 0.14 per cent in the 75,000 to 85,000 lb. per sq. in. range are so insensitive to the rapid cooling under these conditions that the degree of hardening is inappreciable and the steels may be considered foolproof from this standpoint. This is particularly important and is true for all the steels of lower carbon content (under 0.14 per cent in general) in each one of the groups previously mentioned, no matter whether chromium, manganese or nickel is the alloy base.

In the higher carbon range of the steels in question, whose tensile strengths are 90,000 to 100,000 lb. per sq. in., the effect of the very rapid cooling is not negligible but it can be controlled. There is a moderate increase in hardness, which in itself is not a matter of very grave concern, particularly in butt welds. However, internal stresses are produced in welding these very high-yield, high-ultimate-strength steels, and it is common practice and sound engineering to stress-relieve most structures built with these steels. The stress-relieving operation not only does what its name implies—relieves the stresses— but in additon is a true tempering or annealing treatment. Any increase in hardness that may have resulted during the welding is reduced to practically the initial level by this treatment. Because this stress-relieving is desirable and considered necessary by the profession, we cannot call these steels foolproof from the welding standpoint. They must be handled intelligently.

Corrosion Resistance and Heat-Treatment

So much has been said about the corrosion resistance of the new steels that no discussion can pretend to be complete without a word on this subject. It seems to be fairly well established that copper, phosphorus, silicon and chromium—either alone or in combination—increase resistance to corrosion under some conditions, and under many conditions this increase may be of a very appreciable order of magnitude depending on the quantity and combination of the above-mentioned elements and the specific corroding conditions.

Copper has been added to these steels primarily for corrosion resistance. Copper also gives an increase in strength and the mechanism of this increase is probably the well-known precipitation hardening. The effect can be induced to a very much greater degree by a special heat-treatment. Due to the presence of about 1 per cent copper in the as-rolled condition, an increase of some 5000 lb. per sq. in. is noted. If a special heat-treatment is applied, which consists of both normalizing and drawing, as much as 20,000 lb. per sq. in. increase may result. Whether this may be achieved without a disproportionate loss of ductility is a controversial question. Moreover, it is a rather academic question for the time being, because once the steel has been given that heat-treatment it is essential that the structure never again be subjected to a high temperature. A repair on a car fabricated of steel so heat-treated is out of the question because it would reduce the tensile strength 20,000 lb. per sq. in. Conservative engineers, including the promoters of these steels, do not advocate taking advantage of the increase in strength by artificial precipitation hardening.

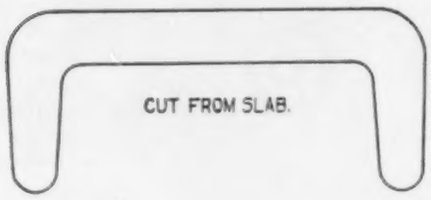
Another phase of this subject which requires mention is the tendency of the higher copper steels to show surface checking unless suitably protected by means of other additional elements. Nickel seems to be the outstanding element for the protection of steels containing 1 per cent or more of copper, but chromium, manganese and silicon—alone or in combination—have been used effectively to prevent checking in steels containing up to 0.6 per cent copper, such as the well-known Cor-Ten, Cromansil-copper, Chromador, Union Baustahl and Krupp Manganbaustahl types, all of which contain no nickel.

In considering corrosion resistance, phosphorus requires special mention. It is generally agreed that phosphorus increases the corrosion resistance under many service conditions, particularly when used in combination with copper. Generally, chromium is used with the phosphorus to offset some of its other effects. Recently, however, it has been claimed that in the lower carbon steels, phosphorus acts like carbon and carries with it no correlated phenomena which require the presence of chromium for the elimination of these effects.

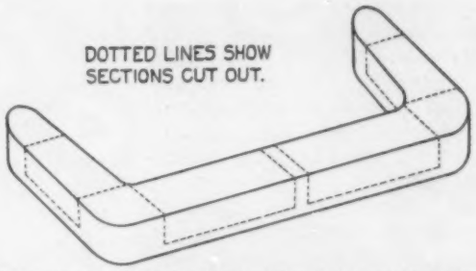
Summary

To sum up briefly, ultimate strength would still seem to be the major criterion for steels for light-weight construction, with ductility and insensitivity to welding operations as the prime adjuncts and with improved corrosion resistance as a desirable feature. Various types of alloy steels have been developed which meet the above-mentioned requirements, and as far as those properties which are usually measured are concerned there is little significant difference between them.

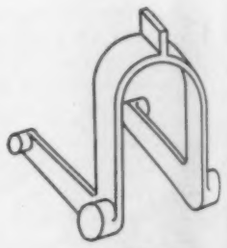
It will remain for service experience and the full evaluation of those properties which are not susceptible to laboratory measurements, to determine the relative worth of each of the steels in question. The final choice of any particular one will depend upon the balance of this worth and the economics involved.



The First Cut in 9-In. Steel Was Made in the Usual Way



Rearrangement of the Cutting Machine Was the Means of Simplifying the Second Cuts



FINISHED JOB

The Shaped Steel Was Then Heated with the Blowpipe and Bent to Its Final Shape

Shape-Cut Locomotive Parts

By G. B. MOYNAHAN†

New Type Reverse Arms for Locomotives Fabricated by Interesting Shape Cutting Set-Up

THE utilization of flame cutting for the fabrication of heavy parts in locomotive manufacture is extensive and growing steadily as new problems are met and solved through its use. Two recent, similar interesting jobs involved some rather unique ideas with regard to the handling of the shape cutting machine itself.

New designs of parts for the reverse lever mechanism for a certain type of locomotive required the solution of an interesting problem in shape cutting. These parts are known as "reverse lever arms" and "reverse lever crank arms." In each case the requirements for the shaping work were similar, and as a matter of fact the solution of one job, which was worked out first, gave the answer to the second. Essentially the problem was this:

The cutting operations had to be carried out in two planes. The first cuts were made on steel slabs 9 in. thick in the normal position, that is, with the slab lying flat on the material supports. The next cuts, however, were required to be made on the steel at right angles to the plane of the first cuts. When the material was first up-ended to make these next cuts, it was found that the cutting blow-pipe could not be raised sufficiently high. The machine was a standard one and ordinarily handles any but the infrequent extreme job. The problem was overcome easily enough, however, merely by raising the cutting machine on some cribbing to the required height. It was then leveled off carefully and the work accomplished easily enough to set up the work on a production basis.

Left—The First Cut Is Made for the "Reverse Lever Crank Arm." Right—The Completed Part

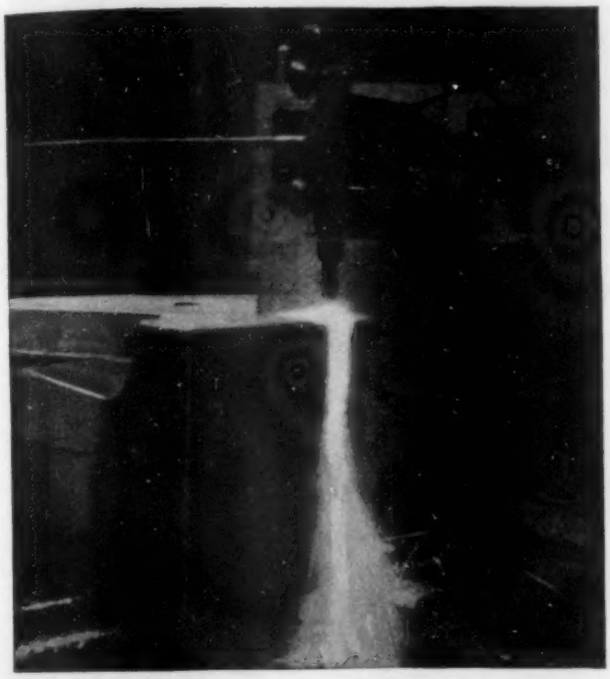
Three-Dimensional Shaping of This "Reverse Lever Arm" Eliminated an Expensive Forging Job

The first work was carried out on the part known as a "reverse lever arm." The rough sketches show the steps required for the formation of this part. Formerly this work had been done by a forging operation.

A steel slab 30 x 69 x 9 in. was procured for the raw material. The first of the three sketches shows the preliminary shape that was cut from the slab. This was a perfectly normal shape cutting job. The regular adjustments of the machine permitted easy handling of this, of course.

It was for the necessary second cuts in the plane at right angles to the first plane of cutting that required the raising of the cutting machine to a new level as described above. As it was necessary to set the steel up on its narrow edge to make these second cuts, it is obvious that considerable ingenuity was shown by the operator in reaching as simple solution to the problem as he did. It was, after all, a simple rearrangement of the machine, but one not generally thought about.

†Oxweld Acetylene Company.



For the "Reverse Lever Crank Arm" Flame Shaping Eliminated Forging and Bending

The third sketch illustrates the completed part after it has been finally bent and finish-machined to the final tolerances and to round out the pads and other parts. Incidentally, it is interesting to know that the heating for bending was done by use of the oxyacetylene flame. The successful conclusion of this first job brought an order for sixteen more reverse lever arms to be fabricated in a similar way.

The work on the "reverse lever crank arms," a similar part, was naturally enough patterned after that done on the "reverse lever arms." Some accompanying illustrations show these parts.

For these later fabricated parts the original steel slabs were 12 in. thick. The work was carried out in an exactly similar way as before. In connection with the preliminary preparation of the steel, it is worth noting that the entire surface of the steel was sand blasted before making any of the cuts. This precaution was made to eliminate any particles of oxide from flaking off and thus interfering with the smoothness of the cutting operation.

Discussion** American Tentative Standard Code for Pressure Piping

By D. S. Jacobus:*

The Code fills a much needed field and the Committee should be congratulated for getting as far as it has in establishing working standards.

More exacting rules will be necessary in some cases. This was brought out forcibly by Mr. James W. Wilson of the Bureau of Navigation and Steamboat Inspection in a paper on "Welded Piping and Pressure Vessels in the Marine Field," presented at a recent meeting of the International Acetylene Association in Cleveland. He said in the paper that at the present time there is an insistent demand and urgent need for extending the Marine Rules to include high pressure piping, and that the successful use of welded boilers and pressure vessels, together with experimental work, seems to justify the development of a Code for welding high pressure piping in position on shipboard. He outlined the hazards and the severe operating conditions to which marine piping is subjected on account of indeterminate stresses due to the pitching and rolling of a vessel, which imposes severe twisting, buckling and pulling, and emphasized the importance of approaching the subject with extreme caution.

A Subcommittee of the Committee on Welding in Marine Construction of the AMERICAN WELDING SOCIETY has been assigned the task of preparing rules to cover the welding of piping for marine use.

There is one provision of the Code which has been questioned, which is the method of rating carbon steel pipe shown in Fig. 1. The proposed method shown in this figure was discussed with the Boiler Code Committee and on April 9, 1934, the Acting Secretary wrote Mr. Sabin Crocker a letter which forms part of the Minutes of the meeting, which read in part as follows:

"In reply to your question whether the Committee would consider cooperating with Sectional Committee B31 in setting S values at temperatures down to 100° F., either along the lines suggested in your letter or in some other manner mutually agreeable to the two Committees, the following is submitted.

"The Boiler Code Committee does not sanction any higher allowable working stresses for vessels subjected to internal pressure than those which are allowable at 700° F. The stress values given in the Code were determined on the basis of experience and the values at 700° F., which correspond to a factor of safety of 5 for the tensile strength of the steel at ordinary room temperatures, are applicable for the entire range from ordinary room temperature up to 700° F. Before departing from this practice satisfactory evidence and facts which would warrant a change would have to be submitted to the Boiler Code Committee for its consideration.

"The Boiler Code Committee would be pleased to cooperate with Sectional Committee B31 in considering evidence that might warrant the setting of S values between ordinary room temperatures and 700° F. at other than a constant value. It would not, however, sanction departing from its present practice of using a constant value for the allowable working stress over this range except on the basis of satisfactory data and a general agreement of authorities on stresses that the change should be made."

The recommendations were not followed and the curve in Fig. 1 does not conform to the rules of the Boiler Code.

The curve shown in Fig. 1 is in line with what was agreed on for flanges where the failure occurs through the yielding of the flanges and where the pressures are in proportion to the yield strength at the different temperatures.

The publication of a method of the sort for piping may make it seem that it would be generally applicable to pressure vessels, which would necessitate wide and important changes in most of our present standards, and as stated in the letter, the Boiler Code Committee would not sanction departing from its present practice except on the basis of satisfactory data and a general

* Advisory Engineer, The Babcock & Wilcox Company.

** Presented at January 21, 1936, Joint Meeting of New York Section, AMERICAN WELDING SOCIETY and Power Division, American Society of Mechanical Engineers.

agreement of authorities on stresses that the change should be made.

It is, of course, wrong for two Committees of the American Society of Mechanical Engineers to promulgate different standards, and there should be some way of coming to an agreement. It would seem that the general practice of using a constant working stress for the lower range of temperatures should be followed unless there is a general agreement of authorities on the subject that this practice should be changed.

By H. L. R. Whitney:†

I have been asked to present my views on the Code for Pressure Piping, particularly the welding section thereof. To put my views briefly, the welding requirements of two A. S. M. E. Codes should be in much closer relation to each other than the welding requirements of the Power Piping Code and the welding requirements of Section VIII of the A. S. M. E. Code, and my opinion that welding requirements and qualification of welders in the Power Piping Code are inadequate for a Code, the major purpose of which is safety, has not changed since my minority report as a member of the Sub-Committee on Welding on the Power Piping Code Committee. My recommendations for revisions and additions to this Code are as follows:

1—The requirements of both field and shop welding of piping systems should be divided into three classes, according to the service to which the piping system is subjected. I suggest the following classes:

(*a*)—For pressures of 400 lb. and over and/or temperatures of 700° F. or over, welders must be capable of producing test coupons which comply with all the requirements of Par. U-68, Section VIII of the A. S. M. E. Code for Unfired Pressure Vessels.

† Chief Engineer, Fabricated Products Division, The M. W. Kellogg Company.

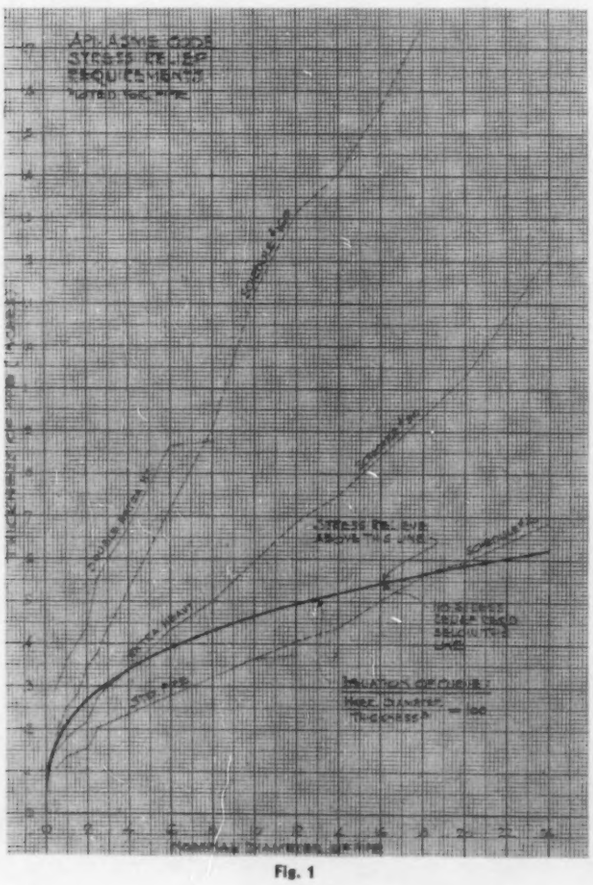


Fig. 1

In addition to the above, welders must be capable of producing sample fillet welds made by tacking two $^3/_4$-in. pieces of steel about 12 in. long together with an angle of 90 deg. between them. See Fig. 2. This 90 deg. edge is placed on an angle of 45 deg. to the vertical. The space between these two plates is then filled with weld metal $1^1/_2$ in. deep. In other words, the fillet weld is placed between the two pieces of plate. After this welding is done, the weld is cut into two pieces, one of which is stress relieved and the other not stress relieved. Then, 0.505 test bars are cut from the all-weld metal part of the fillet weld. These samples shall meet the requirements of Par. U-68 of Section VIII of the A. S. M. E. Code. See Fig. 2.

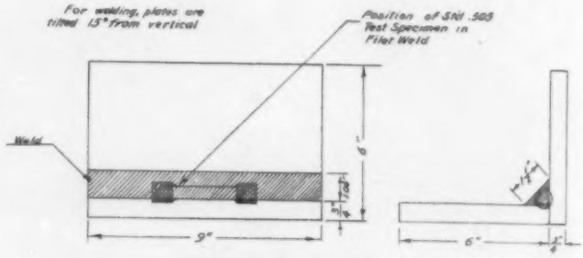


Fig. 2—Sample Fillet Weld

(*b*)—For pressures below 400 lb. down to and including 200 lb. and/or temperatures of from between 699° F. and 250° F., welders must be qualified in accordance with Par. U-69, Section VIII of the A. S. M. E. Code.

In addition to the above, welders must be capable of producing a sample fillet weld the same as described for class (*a*) except that samples cut from same shall meet the nick-break tests of Par. U-69.

(*c*)—For pressures below 200 lb. and/or temperatures below 250° F., welders must be qualified in accordance with Par. U-69 of Section VIII of the A. S. M. E. Code.

In addition to the above requirements, I recommend that all welders making line butt welds in the field shall be capable of butt welding two pieces of pipe together in both horizontal and vertical position, the outward ends of which are rigidly held in position, and that samples cut from these welds shall meet all of the requirements of the class for which the welder is qualifying.

2—In addition to the above, it should be required that chill rings or backing up strips be used for line butt welding of all pipes, unless the pipes are of sufficient size to enter and weld from both sides.

3—For class (*a*) jobs as above outlined, as a minimum requirement, all shop and field welds on pipe falling above the curve shown on Fig. 1 attached hereto, shall be stress relieved in accordance with Par. U-76, Section VIII of the A. S. M. E. Code. This curve is plotted from the requirement of Par. W-318, sub-paragraph (3) of the A. P. I.-A. S. M. E. Code, which requires that a vessel be stress relieved if the ratio of the inside diameter to the cube of the shell thickness at any welded joint exceeds 100. This curve should be modified to include at least 3 in. extra heavy pipe.

My reasons for so strongly recommending stress relieving are that I have never known a properly welded structure to crack when dropped or for any other reason if same has been stress relieved. And, results of a great number of impact tests, made on samples in which most of the locked up stresses are relieved by cutting

samples of so small a size, show consistently higher impact values than unstress-relieved samples from the same weld.

4—Reinforcement of Openings (nozzle connections, etc.).

There is no provision in the present Code whatsoever for the reinforcement of openings and it is a well-known fact to all pressure vessel and structural designers that cutting of a hole in a structure, particularly in the wall of a cylinder, materially reduces the strength of same, and that the stresses at the edge of such a hole if unreinforced, may be from 250 to 300 per cent of the hoop stresses in the wall of the cylinder where there are no holes. It is my recommendation that the latest revision of Par. W-329 of the A. P. I.-A. S. M. E. Code be adopted for the Power Piping Code. This paragraph can be simplified and put in the form of a chart so that any inspector can determine the amount of reinforcement required, and the accompanying cut modified to suit piping conditions.

Tests on Welded Silicon Steel*

By M. R. TAYLOR† AND JONATHAN JONES††

THIS floor as designed comprises $^5/_8$-in. plates resting on and welded to 7-in. I's at 20 lb., spaced 1 ft. $2^1/_4$ in. center to center.

The 7-in. I's run lengthwise of the bridge and are supported on cross joists spaced 7 ft. $3^1/_2$ in. center to center. This floor is paved with 1-in. asphalt plank.

The plates and beams are of silicon steel, specified yield point 45,000, tensile strength 80,000. The analyses of the tested members, which in turn were representative of the material in the bridge floor, were:

	Plates	7-In. Beams
Carbon	0.29	0.27
Manganese	1.00	0.95
Silicon	0.23	0.26
Phosphorus	0.013	0.020
Sulfur	0.024	0.035

As this grade of steel is generally not recommended for welding, and no test data to the contrary was at hand, the fabricator determined to make a test simulating the type of stress to which the welds would be subjected under service in the bridge floor so as to establish their ability to take the necessary punishment, rather than to develop quantitative data.

Preliminary tests gave a 180° bend of a double vee weld around a $2^1/_2$-in. pin. There was found to be an

* Report of repeated-load testing of silicon steel battledeck floor construction for Bronx Kills Span, Triborough Bridge, New York City, Pottstown Fabricating Works, 1935.

† Welding Engineer, Bethlehem Steel Company.

†† Chief Engineer, Fabricated Steel Construction, Bethlehem Steel Company.

Design Data

1 plate 8 x $^5/_8$
1–I 7 in. at 20 lb. $I_{xx} = 81.14$ in.^{4} $\frac{I}{C} = 15.4$ (top), 34.4 (bott.)

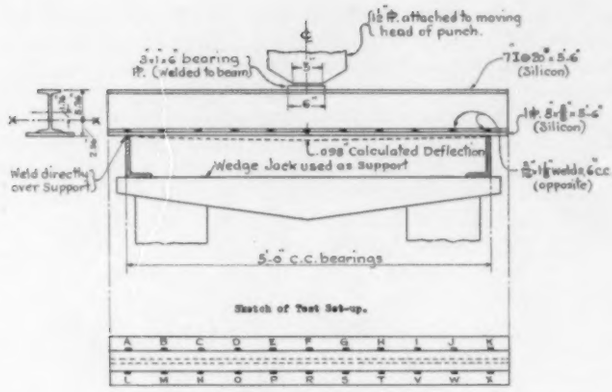
Silicon Specimen	Carbon Specimen
Aim at 50,000 lb. per sq. in. in top flange as tested	Aim at 35,000 do.
$P \times \frac{60}{4} = 50{,}000 \times 15.4$	$P \times \frac{60}{4} = 35{,}000 \times 15.4$
$P = 51{,}200$ lb. central load	$P = 35{,}800$
$V = 25{,}600$ lb. constant shear	$V = 17{,}900$
Bott. flange tension $= \frac{15.4}{34.4} \times 50 = 22{,}300$ lb. per sq. in.	$\times 35 = 15{,}600$
Req. deflection $= \frac{50{,}000 \times 60 \times 60}{12 \times 29{,}000{,}000 \times 5.26} = 0.098$ in.	$\frac{35{,}000 \times do}{do} = 0.069$ in.
Q = statical moment of plt. $= 5.00 \times 2.05 = 10.25$	
Hor. shear per inch of beam $= \frac{VQ}{I} = \frac{25{,}600 \times 10.25}{81.14} = 3200$ lb.	$\frac{17{,}900 \times 10.25}{81.14} = 2260$ lb.
For welds spaced 6 in. c. to c. total weld load = $3200 \times \frac{6 \text{ in.}}{2} = 9600$ lb. per weld	$2260 \times \frac{6 \text{ in.}}{2} = 6800$ lb. per weld
Unit weld load $= 9600/1^1/_8 = 8500$ lb. per lin. in.	$6800/1^1/_4 = 5400$ lb. per lin. in.
Estimated breaking load, $^3/_{16}$-in. welds, 10,800 lb. per lin. in.	8000
Probable ratio, test load to static breaking load, 79%	67%

Test Results

Silicon Specimen	
No. Impacts	Results
9,690	* Welds *B*, *I* cracked
23,500	No further cracks
Welds *B*, *I* chipped out and rewelded. Weld *I* cracked during welding, and was not chipped out again.	
30,310	Welds *B*, *I* cracked
31,445	*B*, *I*, *J*, *L* cracked
34,850	*B*, *I*, *J*, *K*, *L* cracked
51,900	*B*, *I*, *J*, *K*, *L*, *X* were cracked. Test discontinued.

* Weld cracks were faint, may have occurred before noticed.

Carbon Specimen	
No. Impacts	Results
20,400	Weld *A* cracked
26,700	Weld *L* cracked at one end, slightly
88,400	No other welds cracked, but Weld *L* cracked about $^5/_8$ in
Test discontinued.	


½" ℄ attached to moving head of punch.
3"x1"x6" bearing ℄ (welded to beam)
7I@20"=5'-6" (Silicon)
1@ 8"x⅜"=5'-6" (Silicon)
.098" Calculated Deflection
Wedge Jack used as Support
Weld directly over Support
⅜"-1½" welds 6" c.c. (opposite)
5'-0" c.c. bearings
Sketch of Test Set-up.
A B C D E F G H I J K
L M N O P R S T V W X

Plan showing designation of welds

increase of Rockwell "B" hardness from 84 in the parent metal to 95 in the line of fusion. A standard type of fillet tension test (double lap joint) showed 19,000 lb. per lin. in. of $^5/_{16}$-in. fillet, or 86,000 lb. per sq. in. of throat area. A vibratory hammering test, consisting of knocking welded and chilled specimens apart with a pneumatic riveting hammer, showed slightly longer resistance for silicon steel than for companion specimens of structural carbon steel. These tests were satisfactorily carried out with two commercial electrodes; one of which, Lincoln No. 85, was selected for the further testing and for use in executing the contract work.

To more closely simulate the service of the welds in the floor structure, and to again use as the basis for judgment a comparison with a companion specimen of carbon steel, a repeated-load test was conducted as follows:

The silicon specimen and the carbon specimen were made of the same sizes of material, in accordance with the sketch. The welding was detailed the same, but by actual measurement of the finished specimens it was found that the welds on the silicon specimen averaged $1^1/_8$ in. in length, while those on the carbon specimen averaged $1^1/_4$ in.

The specimens were set up one at a time under a punch, and the impact blows were delivered by the head of the punch, at an average speed of 38 strokes per minute. An electrical contact switch was connected under the specimen, and supported on the base, which was set by feeler gage to flash a light at each stroke when the deflection of the beam was as calculated. By check, this switch was accurate within 0.003 in., so that the deflection was within this limit as compared to the calculated deflection, at all times during the test.

It was noted that the carbon specimen had a slight twist after welding, so that it did not seat perfectly on the test supports. This twist was 0.022 in. Allowance was made for this in obtaining the proper deflection of the beam during test. It is believed that this twist, although slight, might absorb an appreciable amount of the impact load to which the beam was subjected.

Particular attention is called to Weld *A*, on the silicon specimen, which, after failure of Weld *B*, was undoubtedly carrying more than its proportionate share of the load. In spite of this, Weld *A* had not failed when the test was stopped.

Supplementary Test

In the foregoing test the carbon specimen obviously stood up much better than the silicon specimen, though the carbon specimen had, as noted, been unintentionally favored as to average length of weld. The comparison was considered to be what might reasonably be expected from the two grades of steel.

In so far as such a test might indicate the probable behavior of the floor in service, it was realized that the stress repeatedly imposed had been unduly high in percentage of static ultimate. A third specimen, of silicon steel, was therefore prepared in which this percentage was reduced from 79 to 40. This still gave a weld stress practically three times that used in the design of the floor. The same design of specimen and the same speed of the punch were employed.

Design Data

As above, except the following:
Aim at 25,500 lb. per sq. in. in top flange as tested.
P = 26,000 lb. central load.
V = 13,000 lb.
Bottom flange tension = 11,400 lb. per sq. in.

$$\text{Reqd. deflection} = \frac{25{,}500 \times 60 \times 60}{12 \times 29{,}000{,}000 \times 5.26} = 0.050 \text{ in.}$$

$$\text{Hor. shear per inch of beam} = \frac{13{,}000 \times 10.25}{81.14} = 1640 \text{ lb.}$$

$$\text{Hor. shear per inch of weld} = 1640 \times \frac{6 \text{ in.}}{2} / 1^1/_8 =$$

4360 lb. per lin. in.
Probable ratio test load to static breaking load = 4360/10,800 = 40%.
Ratio, test load to allowable load for design = 4360/1500 = 2.9 times.

Test Results

This supplementary specimen was tested over a period of 92 hours, the total cycles of loading and unloading totaling 210,000.

As no welds cracked at that number of cycles, the test was considered a satisfactory confirmation of the actual floor design, and was discontinued.

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Welded Structure Design for Dynamic Loads, O. E. Hovey. Eng. News-Rec. (Feb. 27, 1936), vol. 116, no. 9, pp. 310–312. Method of determining endurance-limit unit stresses, main material sections and weld areas, with particular reference to bridge requirements; equivalent maximum stress; working unit stresses; required main material.

Welding Shops. Modern Business Methods Are Necessary for Modern Job Shop, D. E. Randall. Welding Engr. (Mar. 1936), vol. 21, no. 3, pp. 39–40. Simple outline of requirements of organization and methods to be applied in modern welding shop.

BOOK

Theory of the Arc for the Electric Welder, W. Fink. Braunschweig, F. Vieweg & S. 1936, 32 pages, 0.70 RM. Simplified description of voltage and current characteristics of A.C. and D.C. arcs; stability, regulation, magnetic blow, overhead welding.

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

Discount to Members

Attention is called to the following discounts that are available to members of the AMERICAN WELDING SOCIETY on subscriptions and purchases of books.

"Metals and Alloys," the Magazine of Metallurgical Engineering, offers a year's new or renewal subscription at the special low group rate of $1.50 to members of the AMERICAN WELDING SOCIETY. Regular yearly rate is $3.00.

The Iron and Steel Institute offers the two volumes containing the papers presented at the Symposium on the Welding of Iron and Steel, last year, at $8.00. The regular price is $11.00. Orders should be sent to Iron and Steel Institute, 28 Victoria Street, London, S. W. 1, England.

Translations

Through the courtesy of one of the cooperating companies of the Society, there are available two copies of translation "Contribution to the Question of Welding Stresses," by Dr. Ing. Hans Buhler and Dr. Ing. Wilhelm Lohmann, translated from *Die Elektroschweissung*, *Braunschweig*, Vol. 5, No. 8, August 1934, pp. 141–145. The Society will be glad to loan these copies upon request.

Copies of translation made by Dr. G. E. Claussen of article "On the Effect of Small Admixtures in the Welding Wire on the Welding of Copper," by Wilhelm Geldbach, published in *Autog. Metallb.*, **24**, 319–331, 335–345 (1931). (145th Communication from the Metallurgical Laboratory of the Technical College, Berlin—Professor Dr. W. Guertler) are available in the office of the AMERICAN WELDING SOCIETY. Mimeograph copies were made available through the courtesy of another of the cooperating companies.

Instructions in Russian Language

The Board of Education in conjunction with the WPA is giving FREE instruction in Room 401 Engineering Societies Building, daily from 10:00 A.M. to 2:00 P.M. Instruction is given by a native Instructor, Mr. Gabriel Roubin, Electrical Engineer. Enrolment to classes daily.

Welding Book

Special Volume on Welding, 1936, price 6 RM, 25% reduction for foreign delivery. This volume deals with testing finished welds, and the use of different methods of welding for special purposes. The welding of light alloys is also considered. BUCHHANDLUNG DER TECHNIK, DOROTHEEN STR. 32, BERLIN NW7.

A. S. T. M. Meeting

The annual meeting of the American Society for Testing Materials will be held in Atlantic City at Chalfonte-Haddon Hall, June 29th–July 3rd, inclusive. Some twenty different sessions are scheduled. There is to be a symposium on x-rays and sessions on non-ferrous metals and iron and steel.

Heating, Piping and Air Conditioning Contractors National Association

An invitation has been extended to the members of the AMERICAN WELDING SOCIETY to attend the Forty-Seventh Annual Convention of the Heating, Piping and Air Conditioning Contractors National Association, which is to be held in Philadelphia, Pa., May 25 to 27, 1936.

German Welding Course

The University of Karlsruhe, Germany, announces a summer course this year,

July 1 to July 16, 1936, dealing with recent advances in all branches of engineering. The present status of welding and welding processes in the construction of buildings, machinery, tanks and vehicles will be dealt with in lectures by Prof. Dr. A. Kessner, who will also discuss new theories of the strength of materials.

Bradley Stoughton Honored

Professor Bradley Stoughton, Head of the Department of Metallurgy, has recently become Lehigh's first Dean of Engineering, by action of the Board of Trustees. The growth of engineering at Lehigh has continued steadily for many years, until finally coordination of the various engineering departments under one head became advisable.

As Secretary of the American Institute of Mining and Metallurgical Engineers from 1913 to 1921, Bradley Stoughton made a host of friendships throughout the engineering world. During the stress of the war years he served on numerous national committees. In 1922, under the administration and support of President Harding, he prepared a report on the twelve-hour day in the steel industry, resulting in the adoption of the eight-hour day.

In 1923 he was called to Lehigh to occupy the chair in metallurgy left vacant by the death of Joseph W. Richards. Previous to his Secretaryship, he had been Adjunct Professor of Metallurgy at Columbia with Professor Henry M. Howe and while there, in 1908, had written his "Metallurgy of Iron and Steel," for twenty-five years the standard text in this field in the English language. In 1922 he was elected President of the American Electrochemical Society.

Simultaneously with the selection of Professor Stoughton as Dean is the re-establishment of the Ph.D. degree in Metallurgy at Lehigh, after a lapse of forty-two years. Those interested in the advancement of engineering and of metallurgy everywhere will find satisfaction in the new recognition thus accorded them.

Professor Stoughton has been quite active in the work of the AMERICAN WELDING SOCIETY.

By-Law Amendments Effective April 10, 1936

Article X

Bureau of Welding Research

Section 1.—The AMERICAN WELDING SOCIETY shall provide the means for co-operative research in welding by creating a research bureau to be known as the "Bureau of Welding Research," which shall consist of the Chairmen of its technical and research committees and 12 members appointed by the Board of Directors of the AMERICAN WELDING SOCIETY and one representative of each of the other interested societies, associations and governmental departments as indicated in Section 2.

Section 2.—With the intention of making the Bureau the coordinating agency for welding research throughout the country the following bodies shall be invited to designate representatives:

American Bureau of Shipping
The Electrochemical Society
American Institute of Electrical Engineers
American Institute of Mining & Metallurgical Engineers
American Institute of Steel Construction
American Physical Society
American Society for Metals
American Transit Association
Assn. of American Railroads
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Refrigerating Engineers.
American Society for Testing Materials
Bureau Veritas
Engineering Foundation
Lloyd's Register of Shipping
National Research Council
Society of Automotive Engineers
U. S. Navy
Federal Board of Vocational Education
Bureau of Navigation & Steamboat Inspection, U. S. Department of Commerce
Bureau of Standards, U. S. Department of Commerce
U. S. Army
Bureau of Surety & Casualty Underwriters
Bureau of Public Roads, U. S. Dept. of Agriculture
National Board of Fire Underwriters
American Association of State Highway Officials*
American Petroleum Institute*
American Society of Heating & Ventilating Engineers*
Heating, Piping & Air Conditioning Contractors Association*
International Acetylene Association*
National Electrical Manufacturers Association—Welding Section*

Other societies, associations and governmental departments may be invited to appoint representatives upon the approval of the Board of Directors.

Section 3.—Funds for the work of the Bureau shall be secured by voluntary contributions by solicitation or appropriated from the regular funds of the Society. The solicitations of such funds shall be made with the approval of the Board of Directors.

Section 4.—Officers. The officers of the Bureau shall be a Chairman and a Secretary, appointed by the President, with the approval of the Board of Directors.

Section 5.—The Bureau shall create from time to time, research subcommittees, the personnel of which shall be selected by the Chairman of the Bureau with the approval of the Board of Directors.

Section 6.—Meetings. Meetings of the Bureau shall take place at the call of the Chairman. Notices of all meetings of the Bureau shall be mailed to the members at least two weeks prior to the time of such meeting. Twelve members shall constitute a quorum.

Section 7.—Publications. Publications of the Bureau in the form of papers will in general be printed in the Journal of the AMERICAN WELDING SOCIETY. Committee reports carrying the authority of the Bureau must receive the approval of the majority of the members of the Bureau and the Board of Directors. Contributed research reports not implying the approval of the Bureau shall carry the name of the individual authors and shall be subject to the same regulations as any other paper presented to the AMERICAN WELDING SOCIETY.

Section 8.—Custodian of Funds. The custodian of research funds shall be the AMERICAN WELDING SOCIETY or any other body designated by the Board of Directors.

* Added by Executive Committee, April 7, 1936.

Steel Tubes

Welded Steel Tubing has been used for many years. One of the early large volume uses was in the manufacture of bicycles and continues today in its wide application for this purpose. Along with this application, new outlets for the use of welded steel tubing have rapidly opened up; such as in the making of household equipment, office appliances, factory devices, agricultural implements and every place where a light, strong structural section has its advantages. These developments have created hundreds of uses for Welded Steel Tubing.

With the advent of the automobile there was created a demand for Welded Steel Tubing with the result that it has become known as a basic commodity. The rigid demands of the Automotive Industry have required a marked increase in the quality and standards of the product.

The Formed Steel Tube Institute has issued a Handbook to give to the user a thorough knowledge of the application of Welded Steel Tubing; its physical, chemical and metallurgical properties, commercial tolerance limitations and extensive engineering data as a guide and aid to both engineers and laymen.

SECTION ACTIVITIES

BOSTON

The following officers of the Boston Section were elected for the year 1936-1937.

Chairman—H. N. Ewertz, Austin Hastings Co.
Vice-Chairman—P. J. Horgan, General Electric Co.
Secretary-Treasurer—P. N. Rugg, Edison Electric Illuminating Co.
Directors for two years:
P. C. Idell, The Babcock & Wilcox Co.
H. P. Peabody, John A. Roebling's Sons Co.
W. B. Strathdee, Westinghouse Elec. & Mfg. Co.
Trustee:
A. L. Coombs, Linde Air Products Company.
Director of the National Society:
L. F. Jackson, Linde Air Products Co.

CHICAGO

The regular monthly meeting of the Chicago Section was held on April 24th, at the Mission Hall, Armour Institute of Technology. The meeting was presided over by P. C. Huntley, Professor of Mechanical Engineering, Armour Institute. A lecture course on "Metallurgy as Applied to Welding," was given by Jules Muller, Chicago Steel & Wire Company. A talk and demonstrations by E. W. P. Smith, Consulting Engineer of The Lincoln Electric Company, on "Designing for Welding," was next on the program. Mr. Smith demonstrated the effect of design on stress concentrations by means of rubber models and also with the polariscope. Lively discussion followed.

The subject of the May 22nd meeting will be "Weld Testing and Inspection." This will be the last meeting of the season.

DETROIT

A meeting of the Officers and Executive Committee of the Detroit Section was held on Friday, April 17th. Col. A. S. Douglass was re-elected for another term as Section representative on the Board of Directors. A Nominating Committee was appointed, which met and unanimously nominated the following officers:

Chairman—J. D. Tebben, P. R. Mallory Co.

Vice-Chairman—Jos. Matte, Jr., Albert Kahn, Inc.

Sec.-Treas.—Neal Looney, Fisher Body Corp.

A joint meeting of the A. I. E. E. and AMERICAN WELDING SOCIETY was held on April 22nd at the Detroit Edison Auditorium. "The Story of Electric Welding in the Automotive Industry" was presented by Mr. Otto Dinger, of The Chrysler Corporation, Dodge Division. Slides and movies were used to illustrate the talk, and samples of welds were on display.

LOS ANGELES

The regular meeting was held on April 24th at the Los Angeles Chamber of Commerce Building. Fifty-four members and guests were present. After dinner, the group adjourned to the plant of the Pacific Metals Co. in Los Angeles and attended a "Welding Clinic" on nonferrous metals. In addition to numerous exhibits of welded articles, demonstrations were given on process welding of manufactured products. Both oxyacetylene and metallic-arc methods were employed.

After this extremely interesting and instructive "clinic" drawing was made for a door prize and refreshments were served by the hosts.

MARYLAND

At the final meeting of the season held on April 17th, the following officers of the Maryland Section were elected:

Chairman—Bela Ronay
Vice-Chairman—Leon C. Bibber
Secretary—C. H. Hilbinger
Treasurer—A. B. Cromer

Mr. Ronay will represent the Section on the Board of Directors.

MILWAUKEE

The regular meeting of the Milwaukee section was held on Friday, April 17th, at the Milwaukee School of Engineering. Mr. A. E. Gibson, Vice-President of the Wellman Engineering Company, was the speaker of the evening and gave an illustrated talk on "Low Alloy Steels—Properties, Treatment and Uses." There were about 150 members and guests present.

NORTHERN NEW YORK

At the April 28th meeting the following addresses were presented:

"Resistance Welding," by R. A. Gilbert.
"Coated Welding Electrodes," by G. G. Somerville.
"Welding of Alloy Steels," by E. F. Potter.

The speakers were all of the Pittsfield Works Laboratory of the General Electric Company.

PHILADELPHIA

Members of the Philadelphia Section were invited to join with several other engineering societies in an inspection trip to the Bethlehem Plant of the Bethlehem Steel Company on Friday, April 17th. The following was the schedule of the trip:

Round trip transportation by Special Train.
Luncheon at Bethlehem Steel Co. Plant.
Three-hour trip through the plant.
Dinner at Hotel Bethlehem.
Papers presented after dinner by Bethlehem Steel Co. Engineers.

The Annual Meeting of the Section was held on April 20th in the Auditorium of the Engineers' Club. H. N. Wallin, Lieut. Commander, U. S. N., spoke on "Some of the Problems Which Arise in Connection with Welding in Ship Construction."

PITTSBURGH

The last meeting of the Spring session of the Pittsburgh Section was held on April 15th in the William Penn Hotel, jointly with the Mechanical Section, Engineers' Society of Western Pennsylvania and the Pittsburgh Section, American Society of Mechanical Engineers.

At that time Robert E. Kinkead, Consulting Engineer, presented a paper on the design of metal structures with reference to welding, and Dr. Antonio Longoria, Consulting Electrical Engineer, gave a talk on some recent electrical developments in welding.

One of the largest crowds ever to attend a section meeting turned out to hear these two brilliant speakers, and were enthusiastic in their comments on the matters discussed.

Mr. Kinkead gave those present something to think about with respect to farsighted developments which may be looked for by those who expect to lead the field in welding.

Dr. Longoria astounded those present with discussions of some electrical developments which have been consummated already, and an idea as to what is yet before those who have welding at heart.

SAN FRANCISCO

The regular monthly meeting of the San Francisco Section was held on April 24th at the Oakland Airport. The speaker of the evening was Mr. A. F. Bonnalie, Director of Technical Instruction at the Boeing School of Aeronautics, who spoke on "Incidents in Aviation." Following this papers were presented by Walter McGinty on "Design for Welded Aircraft"; David Retan "Aircraft Welding and Construction" and H. R. Brentlinger, "Welding in Aircraft Maintenance."

EMPLOYMENT SERVICE BULLETIN

POSITION VACANT

City of Detroit, the Civil Service Commission, 15th Floor, Water Board Building

The Civil Service Commission announces an examination for: ASSISTANT ELECTRICAL ENGINEER (PUMPING PLANT DESIGN). Minimum Induction Salary—$3600 a year (subject to salary ordinance deductions). Estimated number of present vacancies—four.

DUTIES STATEMENT: Under direction to design electrical equipment and related auxiliaries for large electrically operated water or sewage pumping plants; to perform important and technical field work on such equipment including inspection during installation and erection and the conducting of operation and acceptance tests; to supervise others on the less difficult phases of such work; and to perform related work as required.

All applicants must be of good health, habits and moral character and citizens of the United States. For this examination there are *no* local residence requirements.

There is also the possibility of an examination for Associate Electrical Engineer with similar duties but of a higher level with a minimum induction salary of $4200 a year.

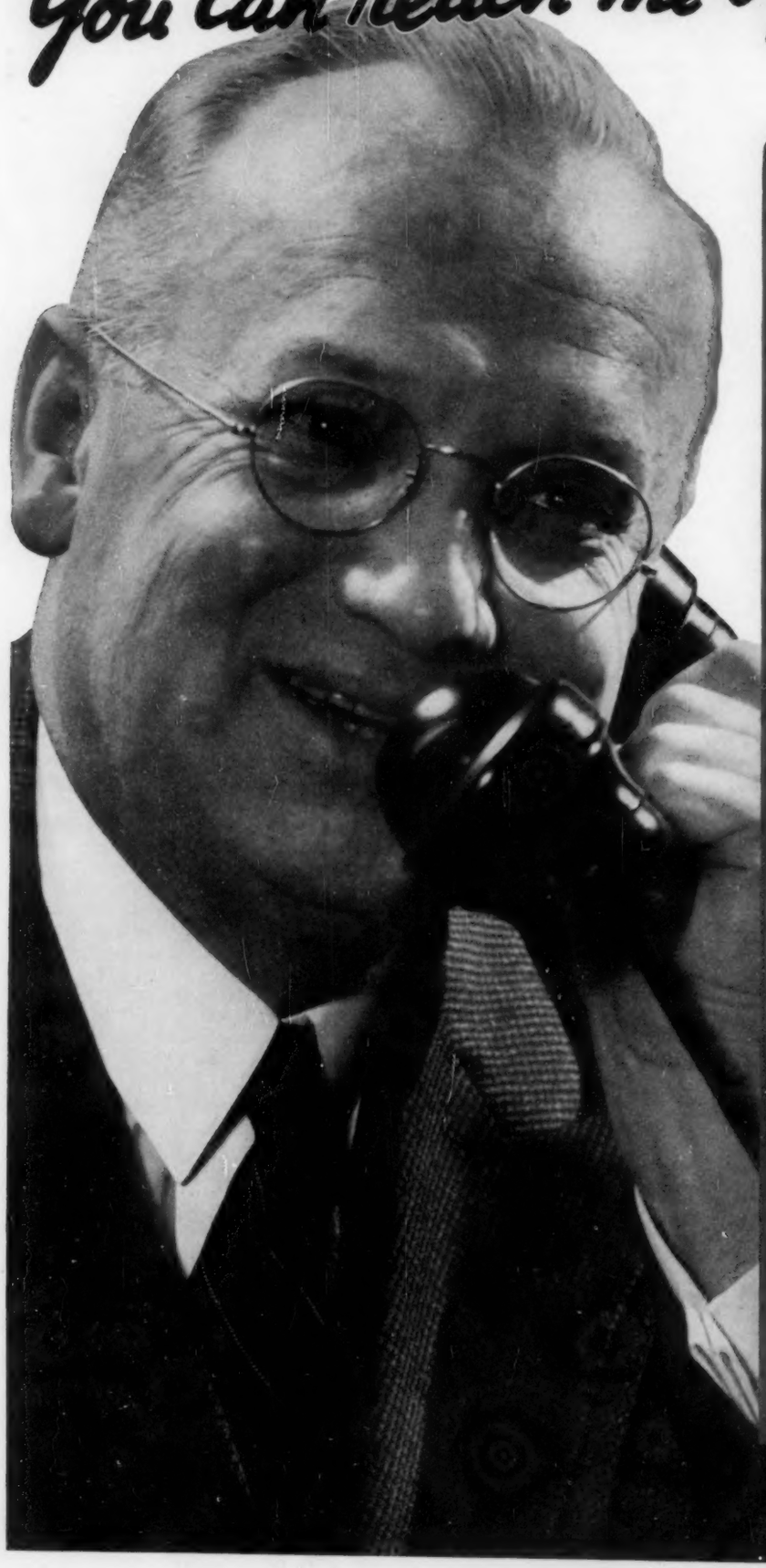
SERVICES AVAILABLE

A-227. Supervisor, Inspector or Instructor of Arc Welding. Steel or Arc Welding Equipment Salesman. 8 years' experience. Knowledge of Metallography, Heat-Treating and Physical Metallurgy. Member A. W. S. and A. S. M. Available July 1st.

A-228. Welding Engineer, shop and field work, design, training welders. Temporary assignments welcome. Established record for improving quality and cost reduction. Now in Pittsburgh.

A-229. Welder. Have had about five years' experience in welding truck bodies, job shop welding, printing machinery and shipyard work. Present location New York.

"You can reach me by Telephone"



"You can reach me by telephone" . . . you say it casually, but there is assurance in your voice. For you can depend on telephone service. You call a number and a voice answers—across the street or across a continent. It's so easy to do — you have been doing it for years. Use has dimmed the wonder of the telephone.

Yet the wonder grows — there is no ending to telephone progress. Service is quicker, clearer and more accurate. Improvements are made each year. Things once thought impossible are now accomplished fact. Tomorrow will see still greater achievement.

That is the pioneering spirit of American enterprise. American initiative and American resourcefulness have given this country the best telephone service in the world.

Obviously this did not just happen. It has been brought about by the development of the Bell System over the past half-century. Time has proved the rightness of its plan of operation. Quick, dependable, universal service makes it possible for you to talk to almost every one, everywhere, and to say confidently — "You can reach me by telephone."

Ten years ago it took, on the average, 20 minutes to put through a long distance call between New York and San Francisco. Today it takes less than 2 minutes. The cost of a daytime station-to-station call between these points is now 45% less than in 1926.

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